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Methods of Improving the Skating Rink of a Potato Harvesting Roller Machine

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Abstract: *Potato harvester is a semi-automatic digging machine and acts as digs the potato beds, carrying/conveying loose soil with potatoes with high speed rotating flat conveyer belt atits high speed rotation which separate the potato tubers from soil. The exposed tubers from soil is then handpick from the soilsurface. Potato harvester consistsof (i) digging blade, (ii) conveyer flat chain, (iii) guide plate, (iv) power transmission arrangement. There are two model of potato harvester; (i) power take fly wheel belt pulley to rotate the conveyer chain, (ii) power take from gear box of power tiller and rotate the conveyer chain.*

Keywords: *Potato Harvester,Roller Machine Tool, Skating Rinks, Economic Improvement*

1. Introduction

Potato harvesters are constantly changing in the direction of reducing the cost of human labor and increasing the number of automated processes, accompanied by a combination of technical means. As a rule, during mechanized harvesting of potatoes on loamy soils, when dried after precipitation, a soil crust is formed, which, when destroyed, gives lumps the size of a tuber. Since these soil clods are not sifted out during separation, when they get into the bunker, they clog the potato heap, so the destruction of soil clods is important when harvesting with potato harvesters.Long-term studies of the authors have established that in such conditions the design of the front part of the machine combine with clod-destroying rollers that copy the bed is the most effective, therefore, it is necessary to conduct research in this area with the development of their new designs, which will increase the technical and economic effect of using potato harvesters.

2. The Current State and Trends in the Development of Potato Harvesting Tools

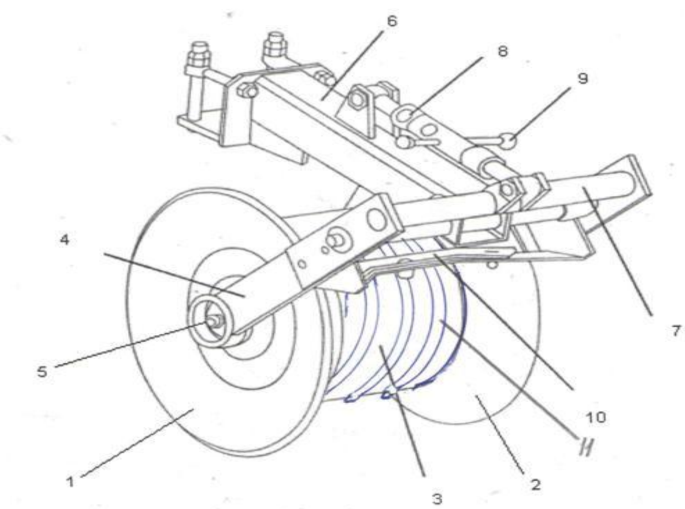
Based on the review, the objectives of the study are formulated:

- Analyze studies on the use of rollers on a potato harvester;
- Theoretically substantiate the parameters of the skating rink of a potato harvester;
- Experimentally refine the parameters of the potato harvester roller;
- Investigate in the field the operation of a potato harvester with an improved roller;
- Evaluate the technical and economic effect of the introductionimproved roller potato harvester.

The study of two key factors of potato production (sown area and yield), as well as the deterministic factorial method of analyzing the multiplicative model of the gross harvest, showed the promise of using highly productive varieties, the introduction of intensive potato cultivation technologies, modern and improved technical means for its harvesting. The analysis of well-known scientific and technical sources has demonstrated the advantages and disadvantages of existing rollers for potato harvesters.

3. Methods of Improving the Skating Rink of a Potato Harvester

On the basis of theoretical studies, a structural and technological scheme of the rink was developed and an analysis of the forces acting on it was carried out.Figure 1 schematically shows a modernized potato harvester roller.



1,2 - hollow truncated cones; 3 - cylindrical part in the form of a drum; 4 - sidewalls; 5 - bearing supports; 6 -

bracket; 7 - hinged frame; 8 - adjusting mechanism; 9 - handle; 10 - scraper; 11 - rings.Figure 1 - Roller of potato harvester KKR-2 (modernized) When the potato harvester is operating, two hollow truncated cones 1 and 2 compress the tuberous layer and together with the cylindrical part in the form drum 3 destroy soil clods. In this case, the roller fixed on the sidewalls 4 with bearing supports 5 rotates. The soil that sticks to the cylindrical part 3 and the truncated cones are removed with scrapers 10. Rings 11, formed by half rings, destroy the soil lumps of the tuberous layer.On the basis of theoretical analysis, dependences were obtained using the calculation scheme (Figure 2). As studies show, the force that must be applied to the center of the rink for its uniform rolling, taking into account the forces of friction is determined by the formula:

$$P = 2kBr^2(1-cos\theta max)^2 = 2kh^2B$$

(1)

Where B is the width of the rink, m; h-track depth, m; - maximum anglecontact of the roller with the soil over the entire depth of the track; r-radius of the rink, m; kcoefficient of soil volumetric collapse, N/m3. In addition to the force P, the vertical load Q also acts on the roller, which is also determined taking into account the friction forces by the formula:

$$Q=kB.$$

$$r^2(1-cos\theta max)\sin\theta max = kBh\sqrt{2rh-h^2}$$

(2)

Installing the rings on the roller allows you to divide its surface into separate sections, respectively; each section will have a force determined by formulas (1) and (2).Then the total force acting on the track roller can be represented as:

$$=\sum_{i=1}^{n} 2kh^2 B_i, \quad (3)$$

Where n is the number of sections, pcs.; B j-width of the j-th section, m

Vertical load:

$$Q=\sum_{i=1,}^{m} i = \sum_{i=1}^{n} kB_i h\sqrt{2rh-h^2} \quad (4)$$

Similarly, on the surface of the rink with the installation of the ring, the forces act:

$$P_k=\sum_{i=1}^{m} P_{ki}=\sum_{i=1}^{m} 2k\, b_i r_i^2(1-cos\theta_{max})^2=\sum_{i=1}^{m} 2k\, h_i^2 b_i$$

(5)

Wherem is the number of rings, pcs; hj-depth of the rings, taking into account the ring, m; rkradius of the ring, m; bj-width of the ring, m.

$$Q_k=\sum_{i=1}^{m} Q_{ki}=\sum_{i=1}^{m} kb_i\, r_i^2(1-cos\theta_{max})\sin\theta_{max}=kb_i h_i\sqrt{2r_i h_i-h_i^2}$$

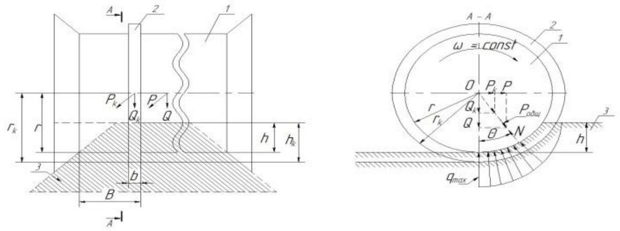
(6)

Taking into account the above dependencies, we determine the total force acting on the structure of the rink:

$$P_{сум}=P+P_k=\sum_{i=1}^{n} P_i+\sum_{i=1}^{m} P_{ki}=\sum_{i=1}^{n} 2kh^2B_i+\sum_{i=1}^{m} 2kh_i^2\, b_i$$

(7)

Also, setting the number of rings increases the number of sections by one; we reduce all parameters to one value by dividing dependence (7) by hj and Bj:



1 - Cylindrical part; 2 - ring; 3 - soil channel

Figure 2—Design scheme of the roller on the soil: Q - vertical force; Qк – vertical force of the roller ring; P - horizontal force; Pк – horizontal force of the roller ring; P total - the total force of the roller on the soil; N - the force of normal soil pressure; r is the radius of the roller; rk is the radius of the roller with a ring; rings; h is the track depth, hk is the track depth from the ring roller; θ – load application angle; qmax – specific load; ω - angular velocity

$$P_{сум}=2k\, h^2(1+\alpha^2)(m+1)B_i(1+\beta),$$

(8)

Where $\alpha=\frac{h_i}{h}, \beta=\frac{b_i}{B_i}$

Let's define the vertical force in the same way.

$$Q_{сум}=Q+Q_n=$$

$$\sum_{i=1}^{n} Q_i+\sum_{i=1}^{m} Q_{ki}=\sum_{i=1}^{n} kB_i\, h\sqrt{2rh-h^2}+\sum_{i=1}^{m} k\, b_i h_i\sqrt{2r_i h_i-h_i^2}=$$

$$kh\sqrt{2rh-h^2}(\gamma+1)(m+1)B_i(1+\beta),$$

(9)

Where $\gamma = \frac{h_i\sqrt{2r_ih_i-h_i^2}}{h\sqrt{2rh-h^2}}$

Using together expressions (8) and (9) and the Goryachkin-Grandvoine formula, we do not determine the track depth:

$$h = \sqrt[3]{\frac{Q^2}{k^2B_i^2(1+\beta)D(1+\varepsilon)(m+1)}}, (10)$$

Where D=2r – skating rink diameter, m; is the ratio of the diameters of the ring andice rink; is the diameter of the ring.Based on formula 10 in the MathCAD program, we will study the depth of the track of the rink from the vertical force and the number of installed rings (Figure 3).

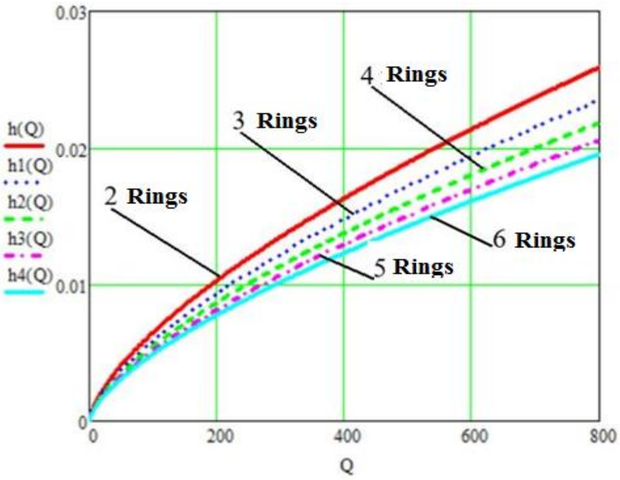


Figure 3 - Dependence of the depth of the track of the rink on the vertical force and the number of installed rings

Dependence analysis shows that with an increase in the load on the roller and a decrease in the number of rings on the roller, the track (pressure of the roller into the soil) and the impact on soil clods increase.

4. Laboratory Studies of the Potato Harvester Rink"

Consider a laboratory research program consisting of three stages.The experimental setup on the soil channel (1) makes it possible to investigate the operation of the roller of the kkr-2 potato harvester (5). The roller is attached to the trolley (3) with a hitch (4) located in front of it. The trolley is driven by a winch and a cable on which a dynamometer (2) is attached (fig. 4).

1 - Soil channel; 2 – traction dynamometer; 3 - movable cart; 4 - hitch; 5 - ice rink.

Figure 4—General view of the laboratory setup

The study of the interaction of the follower roller with the soil was carried out in accordance with GOST 24055-2016. The experimental working body was tested at different soil moisture and with a varying number of rings. The STATISTICA 10 program was used to process the data obtained from experimental studies on the soil channel of the support-copy compressing roller. The resulting regression equation expresses dependence of the specific gravity of large soil aggregates on soil moisture and the number of rings attached to the cylindrical part of the rink. The adequacy of the obtained model is characterized by a high coefficient of determination R2= 0.89.

U_{kk} \u003d 74.616 + 3.8856 * V - 51.234 * n - 0.1411 * V * V + 0.1925*V*n + 7.5517*n*n, (11)

Where U_{kk} is the specific gravity of coarse soil, % V is soil moisture; % n is the number of rings on the roller, pcs.Based on the results of data analysis in the STATISTICA 10 program, a response surface of variable factors was constructed (Figure. 5).

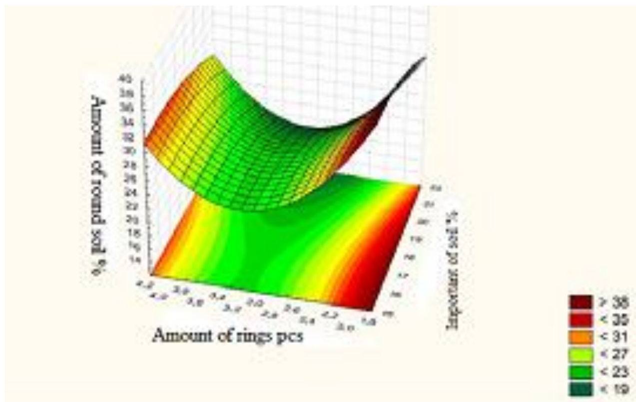


Figure 5 - Graph of the dependence of the specific gravity of large soil aggregates

On soil moisture and the number of rings attached tocylindrical part of the rink. It has been experimentally determined that the smallest amount of soil clods Ukk = 24.17% is achieved when 3 rings are installed on the cylindrical part of the rink and soil moisture is 16%.

5. Economic Tests of a Modernized Potato Harvester with an Improved Roller

The studies were carried out at LLC SolnechnyeLuga, Lukhovitsky District, Moscow Region (KKR-2) and LLC Vereya, Klepikovo District, Ryazan Region (GRIMME SE 150-60). Tests of the semi-mounted potato harvester KKR-2 and GRIMME SE 150-60 were carried out in order to test the efficiency of the improved ring roller compared to the standard configuration (Fig. 6, 7).

1 - ring, 2 - skating rink.

Figure 6 - General view of the serial and improved roller with rings of the KKR - 2 combine

1 - ring, 2 - skating rink.

Figure 7 - General view of the serial and improved GRIMME SE 150-60 potato harvester

The results of economic tests of the improved potato harvester confirmed the results of previously conducted theoretical and laboratory studies, including the efficiency of the developed rink compared to the serial analogue (table 1). Approbation of the improved skating rink of the potato harvester showed positive results. A decrease in the number of soil clods was established by 1.60 times when using KKR-2M and by 1.57 times when using GRIMME SE 150-60M. Also, the percentage of losses decreased by 0.3%; tuber damage decreased by 0.22% according to KKR2M; for GRIMME SE 150-60, the percentage of losses decreased by 0.15%; tuber damage decreased by 0.17%.

Table 1 - Results of studies of the serial and modernized potato harvester KKR-2, GRIMME SE 150-60

The name of indicators	potato harvester			
	KKP-2		GRIMME SE 150-60	
	Serial	Improved	Serial	Improved
1. Timing of testing	September – October 2019 September – October 2020		September – October 2019 September – October 2020	
2. Air temperature, °C	11 – 17°C		12 – 16°C	
3. Soil temperature at tuber depth, °C	9°C		9°C	
4. Working speed of the unit, km/	3.8	3.8	4.2	4.2
5. Completeness of tubers harvesting. %: 5.1. Collected in a container 5.2. Losses	96.7	97.0	96.9	97.05
6. Composition of a heap of tubers				
6.1Tubers	94.6	96.1	95.8	97.0
6.2. Soil clods	4.2	2.7	3.3	2.1
6.3. Plant remains	1.2	1.2	0.9	0.9
7. Damage to tubers, total by weight, %:	3.71	3.49	3.62	3.45
7.1Peeled off from 1/4 to 1/2 of the surface of the tuber	0.71	0.63	0.69	0.67

7.2Peel off more than 1/2 of the surface of the tuber	-	-	-	-
7.3. Pulp slices more than 5 mm deep	0.25	0.24	0,24	0,23
7.4. Cracks longer than 20 mm	0.80	0.80	0.76	0.74
7.5Crushed tubers	-	-	-	-
7.6. Cut tubers	1.17	1.04	1.16	1.04
7.7. Darkening of the pulp from a blow with a depth of more than 5 mm	0.78	0.78	0.77	0.77

6. Economic Evaluation and Results of the Introduction of an Improved Potato Harvester

After we carried out feasibility studies and assessed the economic efficiency of introducing a potato harvester with an improved skating rink. The agro-technical requirements and performance indicators of the KKR-2 combine, as well as regulatory and reference materials were taken as the initial research data for the improved harvester.In order to improve the KKR-2 potato harvester by upgrading the track rollers, investments in the amount of 73,056 rubles are required. At the same time, the total annual economic effect from their use is 16,809.76 rubles.

Table 2 - Annual economic effect from the use of the improved KKR-2 potato harvester compared to the serial version

№	*Name Indicator*	*Designations*	*Unit Measurement*	*Profit (+) l ost (-)*
				Natural Unit
1	*Economic effect as a result of cost increase/decrease in 1 ha*	Z_{YE}	*Ruble*	-7965,61
		Z_{YEGA}	*Ruble/ ha*	-331,90
2	*Economic effect as a result of cost increase/decrease in losses of tubers in 1 ha*	E_{pot}	*Ruble*	17205,12
		E_{potGA}	*Ruble/ ha*	716,88
3	*Economic effect as a result of cost increase/decrease in damage to tubers in 1 ha*	E_{povr}	*Ruble*	7570,25
		E_{povrGA}	*Ruble/ ha*	315,43
4	*Total economic effect in 1 ha*	E_{sym}	*Ruble*	16809,76
		E_{symga}	*Ruble/ ha*	700,41

7. Conclusion

1. The analysis of well-known scientific and technical sources showed a significant number of works devoted to the rollers of potato harvesters. In modern conditions, the importance of ice rinks is underestimated. It has been established that the rollers of the potato harvester can improve the destruction of soil clods, so their modernization should be continued.

2. Theoretical studies have established the relationship between the load and deformation of the soil (track depth), taking into account the geometric parameters of the rink and the physical and mechanical properties of the soil. Dependence analysis showed that with an increase in the load on the roller and a decrease in the number of rings on the roller, the impact on soil clods increases.

3. In the course of a laboratory experiment, it was found that in order for the separation efficiency to not be lower than 79%, and the amount of damage to the potato not more than 1.3%, the final height of the ring is taken to be 8 mm with the number of rings 3 pieces. It has been experimentally determined that the smallest amount of soil clods U_{kk}= 24.17% is achieved when 3 rings are installed on the cylindrical part of the rink and soil moisture is 16%.

4. A decrease in the number of soil clods was established by 1.60 times when using KKR-2M and by 1.57 times when using GRIMME SE 150-60-M.

5. The total economic effect from the introduction of an improved track roller amounted to 16809.76 rubles. (24 ha), including 700.41 rubles per 1 ha.

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