Parameters of passive working bodies of potato digging machine

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Abstract. The major working housing of potato digging machines is a plowshare on which energy costs and the quality of potato digging depend. The examination aims to justify the parameters of the plowshare and the divider of the combined digging working body. The constructive scheme of a potato-digging machine with a combined digging working body, the results of theoretical studies on the substantiation of the primary parameters of the main and intermediate plowshares and the divider, are presented. A special laboratory installation was used to conduct experiments. During the experiments, dividers with different capture widths were made, and the angle of the plowshare installation to the horizon was changed. The degree of damage and loss of the tuber and the traction resistance of the plowshares were taken as evaluation criteria. The outcome of the experimental investigation to determine the parameters of the plowshare is presented. Based on theoretical studies, analytical dependencies, and mathematical models were obtained that allow determining the parameters of the plowshare and the divider of the potato digging machine. It was found that for intensive destruction of the tuberous formation with minimal energy consumption and uniform transportation, the width of the colter of the combined working housing must be 45 cm, the perspective of the plowshare razor solution 90°, the perspective of inclination of the plowshare to the skyline within 27-30°, the length of the plowshare 40 cm, the width of the divider should be 45 cm, its length 39 cm, the angle the solution is 60°, the angle of installation of the working surface to the horizon in the transversely vertical plane is 65° and the range from the toe of the intermediate plowshare to the divider is 32.6 cm.

1 Introduction

In recent years, large-scale work has been transferred out in the republic to increase the area of cultivation and obtain high yields of potatoes. Currently, potato harvesting is carried out by existing machines. These machines do not supply the requested degree of agrotechnical indicators. Their digging working bodies do not destroy the tuberous layer to a sufficient extent, and in difficult conditions, the soil is unloaded in front of them and, accordingly,

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excessive loss of potatoes. The analysis of research has shown that reducing costs, preventing unnecessary losses of potatoes during its digging can be achieved by using a potato digging machine with a combined digging working body consisting of plowshares, right and left augers, as well as a divider M Salimzyanov [1], Y Syromyatnikov [2, 6, 7, 17, 18], M Kostenko [3], F Maiviatov [4], M Edrris [5], F Maiviatov [8], S Hrushetsky [9], F Mamatov [10], B Tulaganov [11], Z Wei [12], J Zhou [13], D Norchaev [14], M Kalimullin [15], M Kalimullin [16], A Semenov [17], K Romaneckas [20], E Sarauskis [21] and others. He developed plowshares of various designs. However, these studies have not sufficiently studied the issues of substantiating the parameters of plowshares and dividers in the conditions of Uzbekistan. The designated objective of the investigation is to argue the parameters of the plowshare and the divider of the combined digging working body of the potato digging machine.

2 Materials and methods

The authors have developed a constructive scheme of a potato digging machine with a combined digging working body (Fig.1). The proposed potato digger (Fig.1) consists of main plowshares 1, augers 2 and 3, intermediate plowshare 4, divider 5 and elevator 6. Divider 5 is installed above the intermediate plowshare 4. Throughout operation potato digger (Fig.1): the main plowshares 1 dig up the club-bearing layer, and the active augers 2 and 3, rotating, cover the club-bearing layer and deforming the soil, destroy the connection between tubers and soil and evenly transport the masses to the separating elevator 6. The intermediate plowshare 5 picks up potatoes not dug up from the side crest and deserted into the aisles. At a similar moment, divider 5 directs the club-bearing mass taken by the intermediate plowshare 4 to the augers 2 and 3, as a result, it is additionally destroyed and uniformly directed to the elevator 6. A laboratory installation was used to conduct experiments. During the experiments, dividers with different capture widths were made, and the angle of the plowshare installation to the horizon was changed. The degree of damage and loss of the tuber and the traction resistance of the plowshares were taken as evaluation criteria.

The main parameters affecting the quality indicators and traction resistance of the potato digger plowshare are the width plowshare P_l; the angle of obliquity of the plowshare to the sky α; the duration plowshare L_l; the sky plowshare toe resolution γ, the width intermediate plowshare and its length L_{ol} (Fig.2).

The breadth plowshare is determined by the following expression, taking into account the provision of full digging up potatoes located in the ridge with minimal soil capture (fig.2).

$$B_l = b_m + 2\delta + 2(h - h_{ct})ctg\varphi \qquad (1)$$

where b_m is the width of the tubers in the nest, cm; δ is the offset of the row axis relative to the plowshare axis, which may occur due to the non-straightness row and inaccuracy of driving the car, cm; h is the depth of digging, cm; h_{ct} is the thickness root emergency in the width of the invest, cm; φ is the angle of natural slope soil, °.

Substituting in (1) 1) b_m=23 cm, δ=3.6 cm, h=22 cm, h_{ct}=18 cm and φ=38º we get B_l=40.44 cm. We accept B_l=45 cm.

The width intermediate plowshare is determined by the following expression, taking into account the working width row interval, the across primary colter, and the width gap among the plowshares (Fig.2)

$$B_{ol} = B_k - B_l - 2b_1 \qquad (2)$$

where B_k is the width aisle, cm; b_1 is the width gap among the plowshares, cm.

Substituting in (2) B_k=70 cm, B_l=45 cm and b_1=3 cm we get B_{ol}=19 cm.

The angle solution γ plowshare toe is definable by the following well-known expression from the condition of cutting plant residues and their roots with sliding along the blade of the plowshare

$$\gamma = 2(\frac{\pi}{2} - \varphi_1) \qquad (3)$$

where φ_1 is the limit value friction angle soil and potato roots along the blade of the plowshare,º.

Substituting in (3) φ_1=40-45º, we determine that the angle of the solution of the plowshare toe should be within 90-100º. We take γ=90º.

The angle of inclination plowshare to the prospect α is strong by the following expression from the condition of achieving the minimum value retaining force formation cut by the plowshare [14].

$$\alpha_{opt} = arctg(-f + \sqrt{f^2 + 1}) \qquad (4)$$

where f is the factor of friction soil on the surface plowshare.

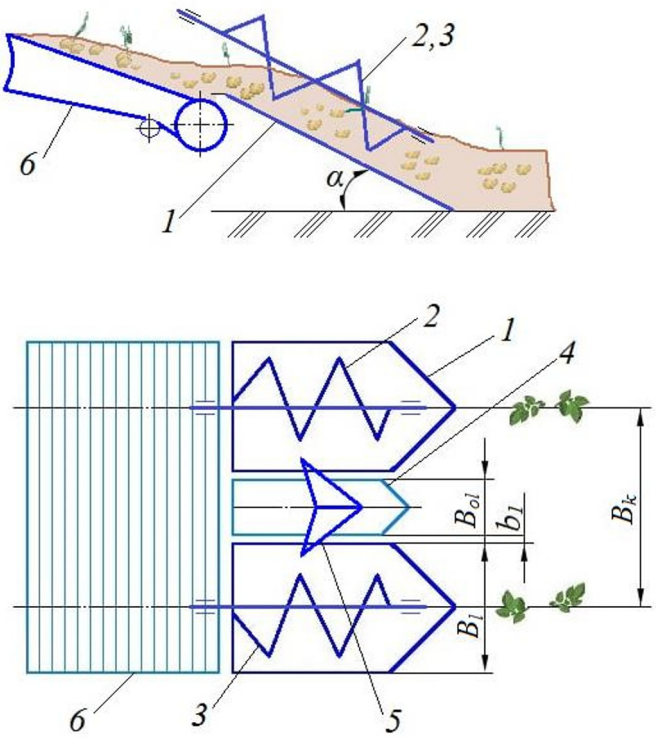


Fig. 1. Technological scheme of potato digger with combined digging working body: 1 is main plowshares; 2 and 3 are augers with right and left turns; 4 is intermediate plowshare; 5 is divider; 6 is elevator

Substituting in (4) f=0,5-0,7, we find that the angle of the tilt of the plowshare to the horizon should be within 27.50-31.5°. We accept α=30º.
The length of the plowshare $L_л$ (Fig.2) according to the following well-known expression

$$L_l = \frac{H}{\sin \alpha} \qquad (5)$$

where H is the height of the location of the end part of the plowshare, cm.

The height of the final part plowshare should be such that the gap between the lower elements elevator and the story groove is at least 40 mm. Based on previous studies, we assume H = 20 cm.

Substituting in (5) α = 30 ° and H = 20 cm, we determine that the length of the plowshare should be L = 40 cm.

Justification of the divisor parameters. The parameters of the divider include its angle of solution $2\gamma_b$, that is, the angle of installation of the working surface of the divider to the direction of movement γ_b, the angle of installation of the operating coating divider to the sky in the transversely vertical plane ε_b, the width of the divider B_b, the length of the working surface L_b and the distance between the toe of the intermediate plowshare and the toe of the divider l_b.

The angle of installation of the working surface of the divider to the direction of movement of the $\gamma_б$ is determined from the condition of the tubers sliding along its working surface

$$\gamma_b = \frac{\pi}{4} - \frac{\varphi_к}{2} \qquad (7)$$

where φ_k is the point of view friction of potatoes on the working surface divider, °.
If φ_k=30º according to expression (7), the angle γ_b should be 30 °.

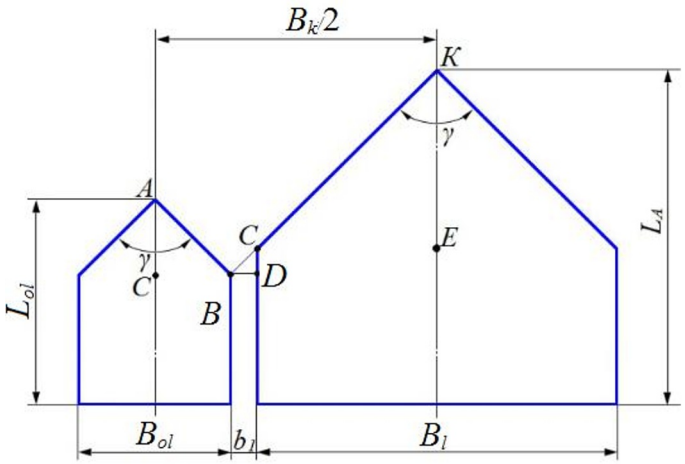


Fig. 2. Scheme for determining parameters of intermediate plowshare

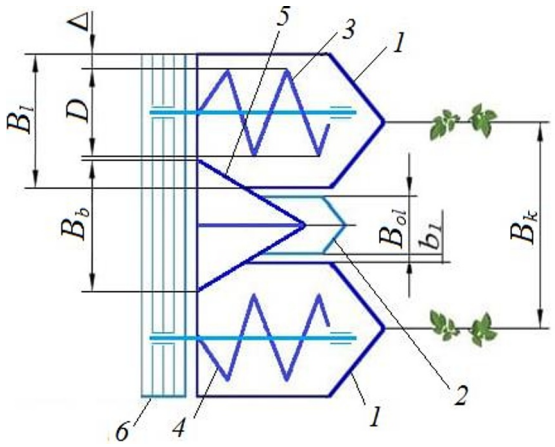


Fig. 3. Scheme for determining width of divider: 1 is plowshare; 2 is intermediate plow; 3 and 4 are screws; 5 is the divider

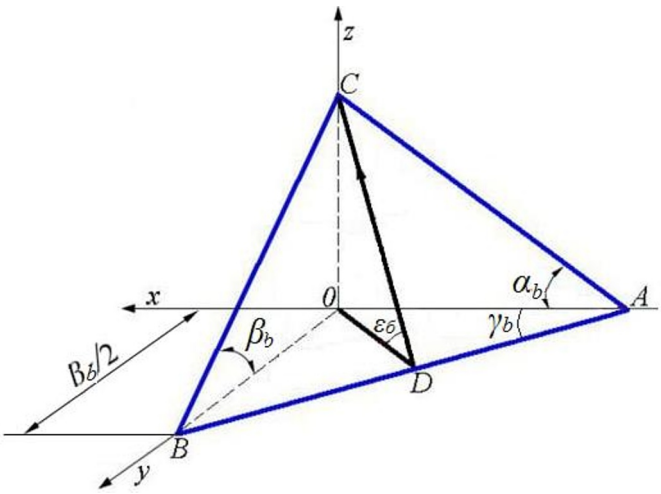


Fig. 4. Parameters of divider

From the condition under which, in the process operation divider, the potatoes should not move in a transversely vertical plane along its working surface (while the potatoes should move towards the auger), we have

$$\varepsilon_b > \frac{\pi}{2} - \varphi_k \qquad (8)$$

Substituting into the expression (8) φ_k=30º, we stipulate that the angle ε_b should be ε_b>60º. We accept 65º.

The distance from the toe of the intermediate plowshare to the toe divider $l_б$ is stipulate from the condition eliminating the repeated losing potatoes in the aisle under the action divider

$$l_b \geq \frac{1}{2} B_{ol} ctg \frac{\gamma}{2} + l_k \qquad (9)$$

where l_m is the largest length of potatoes, cm.

Substituting into expression (9) B_{ol}=19 cm, γ=90º and l_k=23,1 cm, we determine that the distance from the toe of the intermediate plowshare to the toe of the divider $l_б$ should be at least 32.6 cm.

The width of the divider is determined by the following expression

$$B_b \le 2[B_l + \frac{B_{ol}}{2} + b_1 - (\Delta + D)] \cdot \quad (10)$$

For values of B_l=45 cm, B_{ol}=19 cm, Δ=3 cm, b_1=3 cm и D=30 cm, according to expression (10), the width of the divider should be less than 49 cm. We accept B_b=45 cm.

The length of the divisor is determined by the following expression

$$L_b = \frac{1}{2} B_b ctg\gamma_b. \quad (11)$$

Substituting in the expression (11) B_b=45 cm and γ_b=30º we find that the divider length should be 38.94 cm.

To determine the traction resistance of the ploughshare of the developed machine, the following expression is obtained

$$P_{l.} = \frac{\sigma_o t_l B_l}{2\sin\frac{\gamma}{2}} \sqrt{1+f^2}\cos(\frac{\gamma}{2}+\varphi)\cos\alpha + \\ + \left\{\left[\left(B_l + \frac{B_p - B_l}{2(ctg\psi_e + ctg\varphi_p)} ctg\psi_e\right) \times \left(\frac{B_p - B_l}{2(ctg\psi_e + ctg\varphi_p)}\right)\right] + \right. \quad (6)$$
$$\left. + \left[\left(h - \frac{B_p - B_l}{2(ctg\psi_e + ctg\varphi_p)}\right)\left(b_s + \frac{B_p - B_l}{2(ctg\psi_e + ctg\varphi_p)} ctg\varphi_p\right)\right]\right\} \times \\ \times \rho\left[Hg\frac{(tg\alpha + f)ctg\alpha}{(1 - ftg\alpha)} + V_m^2 \frac{f\sin\alpha}{1 - ftg\alpha}\right],$$

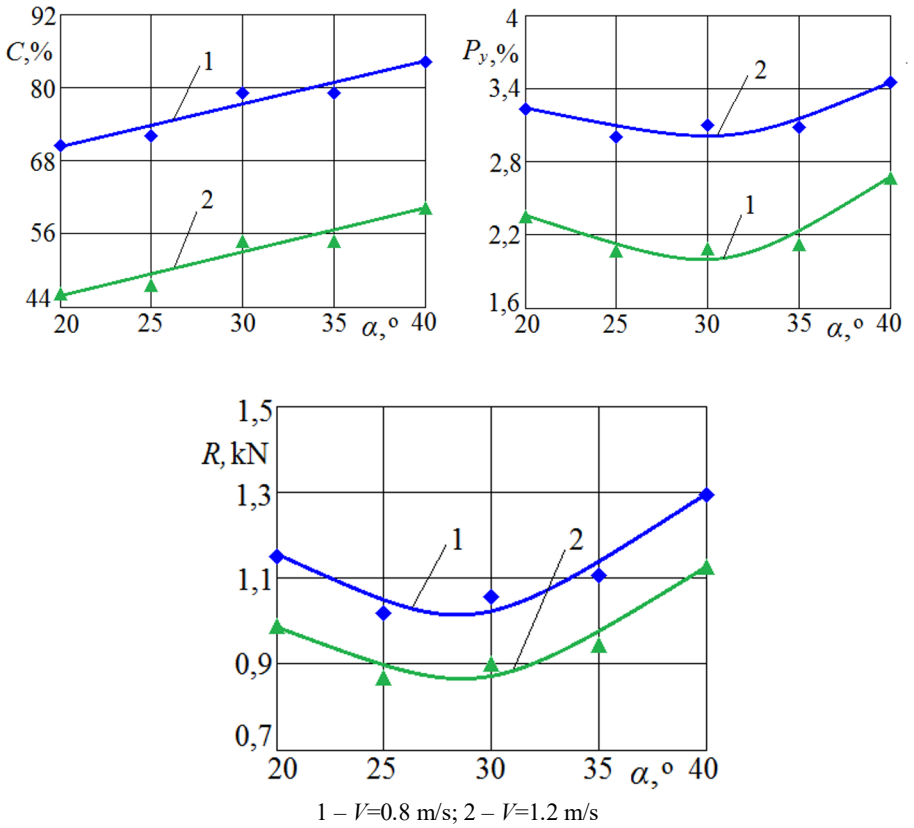
where ρ is the thickness of soil, kg/m^3; V_m is the rate a machine, m/s; h_p is the growth ridge potato field, m; B_p is the latitude ridge potato field, m; ψ_e is the angle cleavage soil in the transverse plane, deg; b_s is the width upper part ridge the potato field, m; b_{pr} is the width gap between the main and intermediate plowshare, m; φ_p is the angle natural slope ridge, °.

The analysis of expression (6) shows that the traction resistance of the plowshare depends on its parameters (L, α, B_l), the depth of digging of the plowshare (h), the physical and mechanical ownership soil (φ_1, ρ, f), the size ridge and the speed of the unit. At L=0,4 m, h=0,2 m, α=30º, B_l=0,45 m, H=0,2 m, ρ=1300 kg/m^3, f=0,58 calculations carried out by expression (6) showed that the traction resistance of the potato digger plowshare at a speed of 0.8-1.1 m/s it is 1.08-1.21 kN.

3 Results and discussion

Experiments were transferred out to determine the optimal parameters plowshare and the divider machine. Plowshares and dividers have been developed and manufactured for experimental research. During the experiments, the extent of disintegrating soil, the degree

of damage and loss tuber, and the traction resistance of the plowshare, were taken as evaluation criteria. At the same time, the experimentation was performed at speeds of 0.8 and 1.2 m/s of the unit. From the results obtained (Fig.4), it can be noticed that with an enhancement in the angle of inclination plowshare, the degree of tuber loss and the traction resistance plowshare initially decreases, then increases according to the law concave parabola, and the degree of soil crumbling increases according to the law straight line. From the data given, it can be noticed that in the combined digging working body, the angle of inclination plowshare should be within 25-30°.



1 – V=0.8 m/s; 2 – V=1.2 m/s

Fig. 4. Graphs of changes in degree soil crumbling (C), degree tuber loss (P_y), and traction resistance plowshare (R) dependent on the angle inclination plowshare to horizon

To cause optimal ratio parameters, combined drilling working body boiler, boilers with a width of 350, 400, 450, and 500 mm were prepared. In these experiments, too, plowshare had a drilling depth of 20 cm, its angle of installation relative to the horizon was 25 hours, the rotational frequency of the machine was 0.8 m/s, and at speeds of 1.2 m/s, respectively, n=3.6 and 4.85 c^{-1} As a criterion for assessing the performance quality index work divider, the loss of potatoes, the damage was adopted. The results reached in the experiments are introduced in Table 1.

Table 1 Influential divisor width on the quality indicators combined excavation working body

Boiler width, m	**Potato loss rate**, %		**Degree of damage to potatoes, %**	
	M_u	$\pm\sigma$	M_υ	$\pm\sigma$
V=0.8 m/s				
0.35	3.20	0.18	2.90	0.20
0.40	3.0	0.19	3.02	0.22
0.45	2.85	0.21	3.09	0.19
0.50	3.05	0.23	3.15	0.17
V=1.2 m/s				
0.35	3.30	0.21	2.93	0.19
0.40	3.10	0.20	3.05	0.18
0.45	2.97	0.24	3.14	0.20
0.50	3.19	0.22	3.26	0.21

Depending on the results study conducted, with an enhancement in the width of the divisor from 0.35 m to 0.50 m, the loss of potatoes initially decreased and increased after. The loss of potatoes decreases when the width of the boiler increases from 0.40 m to 0.45 m. This can be explained by the fact that with increasing the width of the divider, the soil-potato mass being plowed through plowshare provides retransmission to plowshares by resisting lateral displacement using schnecks. The loss of potatoes increased when the width of the hot water heater reached 0.50 m. Depending on the results experiment, with an improvement in the speed of aggregate movement, damage and loss of potatoes increased. With a boiler width of 0.35 and 0.40 m and a device movement speed of 0.8 m/s, potato damage was 2.9 and 3.2 percent, with 1.2 m/s, respectively 2.93 and 3.05 percent. When the width of the divider is small, the potatoes are less exposed to the surface area divider, decreasing their damage. As can be seen from the data represented, the width divider must be 0.45 m for the loss and damage to the potatoes to be at the required level.

4 Conclusions

Resting on the results, theoretical studies, analytical dependencies, and mathematical models were obtained that allow determining the parameters of the plowshare and the divider potato digging machine. It was found that for intensive destruction tuberous formation with minimal energy consumption and uniform transportation, the width plowshare of combined working housing should be 45 cm, the side plowshare knife solution 90°, the side of declination plowshare to the horizon within 27-30°, the detailed plowshare 40 cm, the working width partition wall should be 45 cm, its length 39 cm, the angle the solution is 60°, the angle of installation of the working surface to the horizon in the transversely vertical plane is 65° distance from the toe intermediate plowshare to the divider is 32.6 cm.

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