The influence of the transverse and longitudinal distance of disk skim-coulter on performance of the plough

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Abstract. The article examines influence of the transverse and longitudinal distance from the disk center to the toe of the plowshare body in plan on the performance of the plow. The nature of changes in traction resistance, changes in embedment depth and the influence of longitudinal distance on the nature of changes in embedment depth are also considered. The dependence of the longitudinal distance on the angle attack, depth of passage, sphere radius, disk radius and angle of installation of the ploughshare to the wall of the furrow was studied. Based on the results of experimental studies, influence of the longitudinal and transverse distance from the disk center to the toe of the ploughshare on the clogging of the working parts was studied.

1 Introduction

Soil is a material that is processed by agricultural tools in accordance with the requirements of agricultural technology and, as a material, has different physical and mechanical properties depending on the type, composition and condition [1-3]. The latter circumstance significantly affects the energy and quality performance of tillage machines and implements [4-6]. The creation of new and improvement of existing soil-cultivating working tools is impossible without taking into account the physical and mechanical properties of soil [7,8]. They mainly depend on type and mechanical composition of soil, its moisture and hardness [6,8,9].

Basic tillage gives the soil a lumpy structure [3,6], promotes the accumulation of moisture due to precipitation and irrigation, suppresses the viability of weeds and crop pests, and creates favorable conditions for the development of beneficial soil bacteria [3,6-13].

Removing plant residues or burning them increases the agricultural time required to prepare the soil for sowing. Research has established the following main disadvantages of general-purpose ploughs [3,14-16]. They do not provide a complete rotation of the formation, therefore, they do not embed plant and crop residues to the required depth; the furrow is always half-filled with soil, as a result of which plant residues, organic fertilizers, seeds, alfalfa root rosettes and weed rhizomes are buried finely, the bulk of them remain in the 0–

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13 cm horizon. They do not cope well with cutting the root rosettes of alfalfa and other plants [3].

With the introduction of repeated and intermediate crops into crop rotation, the need arose to plough fields in the summer, when the surface layer of the soil is overdried and significantly compacted, therefore the use of flat disk and cutting knives to avoid ploughing leads to their deepening and, as a consequence, deterioration of the incorporation of plant residues [3,6].

2 Materials and methods

During operation, the disk skim-coulter cuts off a layer of soil that moves along its spherical surface. When sharpening the disk externally, final point of departure from its spherical surface will be on the edge of the blade, and when sharpening internally, at a certain distance from it, determined by plane of the blade chamfer located on the side of the working surface, i.e. the actual radius of the working surface of spherical disk in the second case will be smaller. Consequently, the range of soil rejection, other things being equal, by disks with external and internal sharpening will be different. Therefore, first of all, it is necessary to justify the type of sharpening of the disk skim-coulter, on which the actual radius of the disk, which affects the movement of the soil, depends [6].

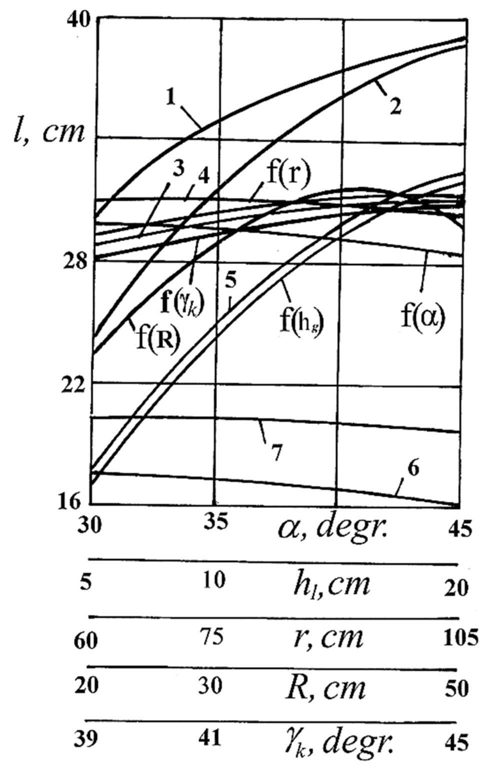

Fig. 1. Relation of the longitudinal distance l on attack angle α, depth h_g of passage, sphere radius r, disk radius R and plowshare installation angle γ_k to the furrow wall. All other values being equal: α=40°; h_g=15 cm; r=60 cm; R=30 cm; γ_k=41°. 1-l=$f(r)$ at R=50 cm; 2-l=$f(R)$ at r=105 cm; 3-l= f(γ_k) at α=30°; 4-l=$f(\alpha)$ at γ_k=44°; 5-l=$f(h_g)$ at α=30°; 6-l=$f(\alpha)$ at h_g=5 cm; 7-l=$f(\alpha)$ at γ_k=390; h_g=10 cm; R=20 cm.

Experimental studies were carried out in accordance with TSt 63.02.2001-"Testing of agricultural machinery. Machines and implements for deep tillage. Test program and methods" using a field strain gauge installation, on which traction resistance of both the main body and skimmer (in our case, disk coulter) can be determined. The installation allows to change, within the required limits, the relative position of the main body and the disk skim-coulter (hereinafter referred to as the disk) both in the longitudinal and transverse and vertical directions, the angle of attack of the disk (the angle between the line of the disk blade in the plan and the directions of movement).

Analysis of the graphical dependencies in Figure 1 shows that the rational values of the longitudinal distance l between the toe of the ploughshare and the disk center, which excludes braking of the disk rotation by soil aggregate cleaved by the ploughshare of the body, increase with increasing depth h_g of the disk passage, its radius R, radius r sphere, angle γ_k of installation of the plowshare to the wall of the furrow and decreases with increasing angle α of the disk attack. Besides, the most intense influence on longitudinal distance is exerted by depth of the disk passage and its radius.

With an increase in the radius R of the disk, the influence intensity of the sphere radius r on longitudinal distance l increases, and, conversely, with an increase in r, the influence intensity of the radius R on l increases. Hence, with R = 30 cm, an increase in r from 60 cm to 105 cm leads to an increase in the value of l from 29.3 cm to 31.6 cm, i.e. by 2.3 cm, and at R = 50 cm from 30.1 cm to 39.2 cm, i.e. by 9.1 cm.

Analogously to r =50 cm and r=60 cm, a change in R from 20 to 40 leads to an increase in l, respectively, by 8.1 cm and 11.9 cm. From Figure 1 it is clear that the reciprocal influence of other parameters (α, γ_k, h_g) is insignificant, they are also small influence intensity of change in the longitudinal distance l according to the disk radius R and radius r of its sphere. The l=f(R) curve has a maximum at R=40 cm; a further increase in radius R leads to a decrease in the longitudinal distance l. The reason is that an increase in R of more than 41 cm (at r=60 cm) leads to the fact that the intensity of the increase in distance from the center (O_d) of the disk to the plane of its blade becomes greater than the distance from vertical plane passing through rotation axis of the disk to the intersection point of its blade and plane of the soil surface increases.

When installing a spherical disk from a disc harrow (R=32.5 cm, r=60 cm) with an attack angle α = 40° (average value of the limit 35–45° [3]) equal to γ_k on a plough with a POT 01.000 (γ_k = 40°) body and calculated (minimum required) depth of its passage determined by formula, the required longitudinal distance l will be equal to 29.2 cm, and with a rational radius (R=34 cm) of the disk 29.6 cm.

$$h_g = h_b = \frac{B_b tg\phi_0}{2},, \qquad (1)$$

where h_b – the theoretical value of the irrigation furrow depth after harvesting wheat, cm;

B_b – the average width of the irrigation furrow, determined as a result of measurements;

φ_0 – average value of the angle of repose of the irrigation furrow, determined as a result of measurements.

3 Results and discussion

Based on the above, it follows that it is necessary to determine minimum possible values of the passage depth h_1 of disk skim-coulter and its radius R (subject to high-quality execution of the technological process), which most significantly affect the longitudinal distance l, and, consequently, dimensions and weight of plough.

In the experiments, transverse distance from the longitudinal-vertical plane passing through the field edge of the body to the rotation center of disk b and longitudinal distance in plan from disk center to the toe of the ploughshare varied respectively within the range

20–10 cm and 10–20 cm in increments of 10 cm. Angle of attack α =40°, taken equal to angle γ_k. installation of the housing ploughshare to the wall of the furrow and based on the results of the experiments. During the studies, the translational speed of the unit was 2.4 m/s.

The results of the research are shown in Figures 2 and 3, from which it can be clear that the traction resistance of the body and disk + housing is minimal at a longitudinal distance l = 15–20 cm, and a transverse displacement of the disk b = - 6– -12 cm. In the range of b values there is a point extreme minimum, as seen from Figure 2. (curve $f(b)$). Analysis of the nature of the change in traction resistance $P=f(l)$ shows that the minimum of this function, taking into account its continuity, can be found at $l > 20$.

The nature of the change in traction resistance $P=f(b)$ is explained by influence of the location of the furrow formed by disk skim-coulter on traction resistance of the body. If the deepest point of the furrow is located on the line of movement of the field edge of the body, then it clears the wall of its furrow with a shallower depth and, therefore, its traction resistance will be less. The displacement of this point away from the line of movement of the field edge leads to an increase in the depth of its passage and traction resistance of the plough body. In addition, the clearing of the path of movement of the field sawn-off edge worsens and the mass of plant residues hanging on it increases, which also leads to an increase in traction resistance of the hull and the likelihood of hull faces.

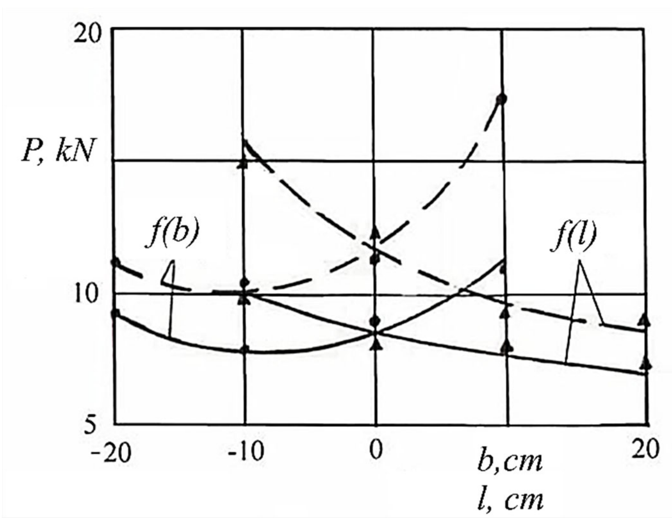

Fig. 2. Influence of l and b on the traction of the housing P resistance. ——————— - housings; - - - - - - - - - - - - general.

The influence of the longitudinal distance l from the disk center to the toe of the ploughshare on the nature of the change in traction resistance $P = f(l)$ is explained by the fact that the approach of the disk skim-coulter to the body worsens the conditions for the passage of soil between them, while disk operates in soil environment deformed by the body, due to which increases its sliding and decreases speed, the mass of soil located on working surface of the disk and its movement in the direction of movement of the plough increases [3,6].

The nature of the change in embedding depth $H_e = f(b)$ Figure 3 is explained by the fact that in the range b = -10– -20 cm the disk throws soil with plant residues to the bottom of the furrow formed by previous body or to the slope of formation cut off by previous disk, which further along slope slides to the bottom of the furrow. This gives a deeper embedment than in the range b = -10– +10 cm when there is an intensive decrease in the embedment depth due to the dumping of soil onto the slope of the furrow.

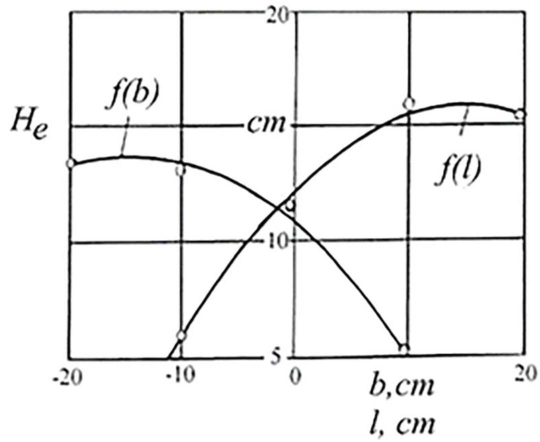

Fig. 3. The influence of *l* and *b* on the depth of embedding H_e of plant residues.

The influence of the longitudinal distance *l* on the nature of change in embedment depth $H_e = f(l)$ Figure 3 is explained by the fact that with an increase, conditions for the passage of soil between disk skim-coulter and subsequent body improves and layer does not jam between them; the soil with plant residues thrown by disk manages to fall to the furrow bottom before layer cut out by body covers it.

From Figure 3 it is clear that the function $H_e = f(b)$ and $H_e = f(l)$ have a maximum, respectively, at $b \approx$ -15 cm and $l \approx 15$ cm.

Analysis of the results (Figure 2, 3) shows that by taking rational values *l* and *b* obtained by calculation in theoretical studies, it is possible to achieve a decrease in total traction resistance (disk + body) and an increase in depth of embedding of plant residues.

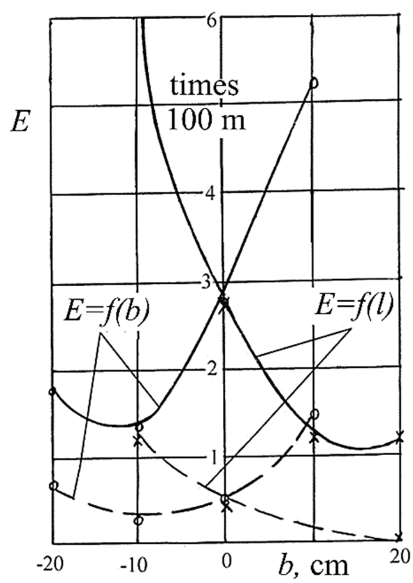

Fig. 4. The influence of longitudinal *l* and transverse *b* distances on clogging with plant residues.

From the results of experimental studies to study influence of the longitudinal and transverse distance from the disk center to the toe of the ploughshare (Figure 4) on clogging of the working bodies, it is clear that the minimum clogging occurs at b = -12– -13 cm (l =0) and b = -8– -10 cm (l = 30 cm) and at =18–20 cm (b=0 and b=-8 cm), the functional dependence $E=f(l)$ in its current values is less at l=20 cm than at l=0. This is explained by the fact that the value of the parameter b = -8 cm provides better cleaning of the path of movement of the field cuttings from plant residues, and the parameter l= 20 cm the highest speed of rotation of the disk, since there is enough space between the body and the disk for the free passage of soil moving along the dump surface the subsequent body and disk in this case operate in the least deformed soil environment by the body, and therefore have less slip.

Installing a disk skim-coulter with parameter values b = –8 cm and l = 20 cm completely eliminates clogging of the working parts with plant residues.

A joint analysis of the technological scheme of operation of a plough with a disk skim-coulter and the functional dependence $E=f(l)$ shows that a further increase $l > 20$ cm is not advisable, since there is no effect on clogging of the working parts, in addition, a shift in minimum of function $E=f(b)$ at l=0 and l=20 cm determines presence of mutual influence of parameters and b.

4 Conclusion

Changing longitudinal distance l from the toe of the share to the disk center in plan from –10 cm to 20 cm reduces traction resistance of both the body (from 10 kN to 8 kN) and the body + disk (from 15.75 kN to 8.75 kN). In this case, the depth of plant residues first increases from 6 cm to 16 cm, then slightly decreases to 15.5 cm.

The following rational parameters for location of the disk skim-coulter and its operating mode were determined experimentally, ensuring high-quality implementation of the ploughing technological process [3] at forward plough speeds of 1.7–2.7 m/s:

- transverse displacement of the center of the spherical disk b = 0– -4 cm;
- longitudinal distance from the toe of the plough share to the center of the spherical disk – l = 20 cm.

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