Substantiation of the transverse and longitudinal distance of the disk skim-coulter

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Abstract. The article discusses the rationale for transverse and longitudinal distance of the disk skim-coulter and the impact on performance of the plough. The issues of transverse displacement of the disk skim-coulter relative to the field edge of the body and longitudinal distance from the toe of the body ploughshare to the center of the disk skim-coulter are also considered. Under established technological process of operation of a plough with a disk skim-coulter, a given depth h_1 of the disk passage, radius R and angle α of its attack, the area cut by disk from the section of the formation processed by body.

1 Introduction

The development of agriculture is closely related to the improvement of soil-cultivating machines and implements. Along with changes in views on depth of ploughing, methods and tasks of basic soil cultivation, soil-cultivating working bodies and machines in general changed. Many methods of basic soil cultivation were tested and improved, starting with the use of primitive tools, the first samples of foreign and domestic ploughs and ending with modern ones. The maximum loosening depth then did not reach 20 cm [1-3], so yields were low and manual labor costs were high. With the advent of industrial models of tractor-drawn ploughs, basic tillage began to be carried out to greater depths and at lower costs [4,5].

Depending on type, reclamation state and age of development, different soils require the use of different technologies for their treatment [1,2,6]. A complete rotation of the formation is necessary for deep incorporation of manure, plant residues, mineral and organic fertilizers [7,8].

Currently, in order to gain grain independence of the Republic of Uzbekistan, significant areas are sown with grain crops by reducing cotton crops. After harvesting grain, a significant amount of biomass of plant residues remains on the soil surface, both associated with soil in form of a stubble background, and stems not connected randomly or in an orderly manner lying on soil surface. The same thing is observed after harvesting vegetables and potatoes.

Timely ploughing of straw immediately after harvesting in combination with immediate pre-sowing soil preparation and sowing of a catch crop increases its yield and provides significant economic benefits [1,9-11].

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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 [2,12-16].

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 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).

2.1 Transverse displacement of the disk skim-coulter relative to the field edge of the body

With a steady technological process of operation of a plough with a disk skim-coulter, a given depth h_1 of the disk passage, radius R and angle α of its attack, the area cut by disk from the cross-section of the formation processed by body will be the same, regardless of the location of the disk relative to the field edge body in a direction transverse to the movement of the plough. Consequently, the cross-sectional area of the formation cut by body, with the same depth h_k of its passage and width b_k of the grip, will be the same, i.e. as can be seen from Fig. 1, the cross-sectional areas (shaded) $a_ob_oc_od_oe_of_o$, $a_1b_1c_1d_1e_1f_1$, $a_2b_2c_2d_2e_2f_2$ will be equal and the plough body will process the same volume of soil in all three cases under consideration. Then, the most rational option for the disk location is when the field edge of the body is buried in the soil to the smallest depth equal to h_k-h_1, i.e. The point b_1 of the disk (option *b*) located most deeply in the soil should be on line 2 (Figure 1) of the trajectory of the field edge of the body. This arrangement of the disk skim-coulter minimizes the height a_1b_1 of the furrow wall, which is cleaned with field edge of the body, respectively, with lower energy intensity than with a higher height (a_0b_0, a_2b_2) in options *a* and *c*. Consequently, with the same volume of soil cut by the body, the technological process of the plough will take place with less energy intensity, when the diametrical section (AD) of the disk blade circumference plane with a vertical plane passing through its axis of rotation will be in plan on the line of movement of the field edge of the body, i.e. in a longitudinal-vertical plane containing the line of its field edge.

When operating a plough with a disk skim-coulter, the most rational option is to position the disk when the field edge of the body is buried into the soil to the smallest depth (Figure 1), i.e. The point (b_1) of the disk (option *b*) located most deeply in the soil should be on the line of the trajectory of the field edge of the body. This arrangement of the disk skim-coulter minimizes the height a_1b_1 of the furrow wall, which is cleaned with the field edge of the body, respectively, with lower energy intensity than with a higher height (a_0b_0, a_2b_2) in options *a* and *c* [1,17].

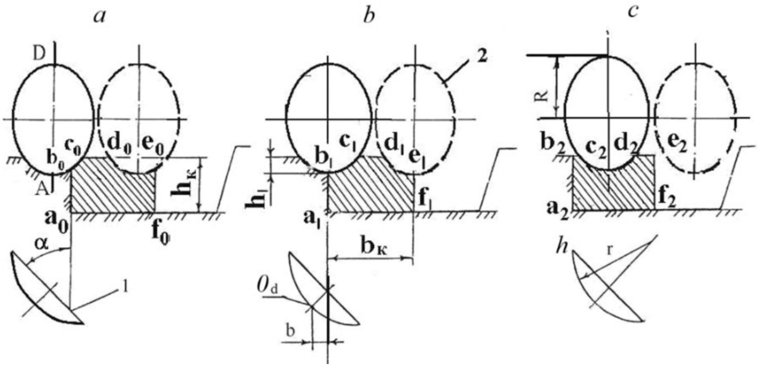
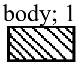


Fig. 1. Options for positioning the disk skim-coulter relative to the field edge of the body. *a*, *c* – with a transverse displacement of the diametral section (AD) of the disk skim-coulter towards unploughed and ploughed fields relative to the field edge of the body; *b* – when diametral section of the disk skim-coulter is located in a longitudinal-vertical plane containing the line of the field edge of the body; 1 – disk skim-coulter; 2 – location of the previous disk skim-coulter;
 – cross-section of the layer cut by the plough body.

The transverse displacement of the disk is determined, as can be seen from Figure 1 (*b*), by formula

$$b = \left(r - \sqrt{r^2 - R^2} \right) \cdot \cos \alpha , \tag{1}$$

where r – the radius of the disk sphere, m;
R – disk radius, m;
α – angle of attack of the disk, degrees.

Analysis of the derived dependence, which satisfies above accepted condition for the location of the disk skim-coulter, in a technologically acceptable range of changes in its design parameters (R, r) and the location parameter (α), shows that with an increase in radius R of the disk, the displacement value b increases, and with increasing radius r of the sphere and angle α of attack, it decreases.

Calculations show that a smooth disk from a disk harrow (R = 32.5 cm, r = 60 cm) installed on a plough as a skimmer at an angle of attack α = 400 (to avoid jamming of soil between the disk and the body, the value of α is taken equal to the installation angle ploughshare body POT 01.000 of the reversible plough to the wall of the furrow), should be shifted relative to the field edge of the body towards the unploughed field 7.3 cm (Figure 1, *b*), and with a rational value of the radius (R = 34 cm) of the disk b = 8,1 cm.

Using formula (1), only the necessary positive displacement of the disk is determined, i.e. towards the unploughed field relative to the field edge of the body [2].

2.2 Longitudinal distance from the toe of the body share to the center of the disk skim-coulter

Existing two-tier ploughs have increased weight and traction resistance compared to general purpose ploughs. Therefore, justification of the rational longitudinal distance between the bodies, taking into account the placement (transverse displacement) of the upper tier body, is of great importance for minimizing the traction resistance of a two-tier plough [2].

The influence of the longitudinal distance l from the center of the disk 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 [3,5].

To eliminate the braking of disk rotation from the impact on its non-working surface of the soil aggregate, which is cleaved by the body plowshare and rising along the moldboard surface of the latter, and in addition to ensure operation of the recessed part of the disk blade in an undeformed soil environment, which will eliminate loading of the soil in front of the disk and ensure reliable support for cutting plant residues. It is necessary that the trace (OBCD) (Figure 2) of the vertical plane of soil chopping by the body ploughshare in plan is shifted relative to the axis of rotation of the disk towards heel of ploughshare by a distance L no less than K, i.e.

$$L \geq K \,, \tag{2}$$

$$K = \sqrt{h_g\left(2R - h_g\right)} \,, \tag{3}$$

where h_g – the passage depth of the disk skim-coulter;

K – half of the chord formed when the plane of the circle of the disk blade intersects the soil surface.

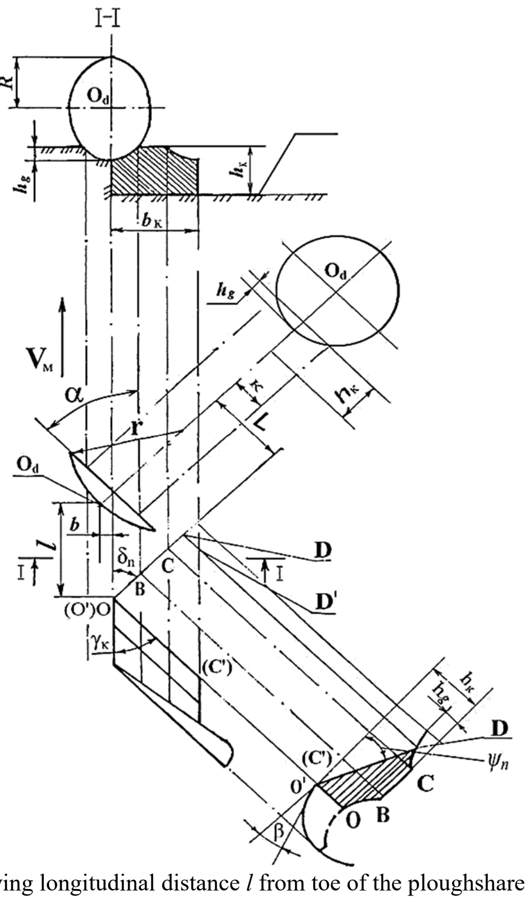


Fig. 2. Scheme for justifying longitudinal distance l from toe of the ploughshare to the disk center O_d and determining range of soil throwing.

Here it is assumed that vertical plane (OBCDO') of soil shear is perpendicular to the plane (O'DD'C') of the shear inclined δ_n to the horizon, and starts from the margin line (O'D) of the last.

3 Results and discussion

For the general case of the disk arrangement, when its rotation axis is not parallel in plan to the OBCD track (Figure 2 shows a particular, i.e. the OBCD track in plan is parallel to the axis of revolution of the disk), we determine the value of L from the next derived formula:

$$L = \frac{\left(l + btg\alpha\right)\sin\delta_n}{\sin\left(\alpha + \delta_n\right)}, \tag{4}$$

where $\delta_n = \frac{\pi}{2} - \gamma_k$ – angle between the ploughs' traffic route and floor projection of the margin line O'D of the shearing plane O'DD'C', degrees [2];

γ_k – angle of setting of the ploughshare blade to the wall of the furrow, degrees.

Substituting into (4) the value δ_n and formula (1), which determines the lateral movement (b) of disk, and transforming it, we obtain

$$L = \frac{\left[l + \left(r - \sqrt{r^2 - R^2}\right)\sin\alpha\right]\cos\gamma_k}{\cos\left(\alpha - \gamma_k\right)}. \tag{5}$$

Equating the left and right parts in formula (2), consideration (3) and (5), we find the smallest longitudinal distance l between toe of the share and disk center (O_d), obey (2), which, for any structurally and technologically acceptable factors included in formula (6) will provide the minimum longitudinal plough dimensions.

$$l = \frac{\sqrt{h_g\left(2R - h_g\right)}\cos\left(\alpha - \gamma_к\right) - \left(r - \sqrt{r^2 - R^2}\right)\sin a\cos\gamma_k}{\cos\gamma_k}. \tag{6}$$

where h_1 – the depth of the disk passage, m;

γ_k – angle of setting of the ploughshare blade to the furrow wall, degrees.

The longitudinal distance from the toe of the body ploughshare to the center of disk skim-coulter was determined from the condition of eliminating braking of the disk rotation from influence on its non-working (rear) surface of soil aggregate, cleaved by body ploughshare, and (6) formula was proposed for its determination.

Using formula (2), the required positive value of the distance l is determined, i.e. from the toe of the share in the direction of movement of the unit.

Analysis using formula (6) shows that the rational values of the longitudinal distance l between the toe of the ploughshare and disk center, satisfying condition (2), which excludes braking of the disk rotation by soil aggregate, cleaved by ploughshare of the body, increases with increasing depth h_g of the disk passage, its radius R, radius r of the sphere, angle γ_k of setting the ploughshare to the wall of the furrow and decreases with increasing angle α of the disk attack. Besides, the most intense influence on longitudinal distance l is exerted by depth h_g of the disk passage and its radius R.

With an increase in the disk radius R, intensity of the radius r influence of the sphere on longitudinal distance l increases and, on the contrary, with increasing r intensity of the radius R influence on l increases.

Calculations showed that at R = 34 cm the required longitudinal distance l = 29.6 cm.

In experiments, the transverse distance from the longitudinal-vertical plane passing through field edge of the body to the rotation center of disk b and longitudinal distance in plan from the center of the disk to the toe of the ploughshare varied respectively within the range 20–10 cm and 10–20 cm in increments of 10 cm The angle of attack α = 40º, the forward speed of the unit was 2.4 m/s.

4 Conclusion

The transverse displacement *b* of the disk center in plan relative to the toe of the ploughshare towards the unploughed field from 0 to –20 cm first leads to a decrease in the traction resistance of the body from 8.5 kN to 7.75 kN and the body + disk from 11.5 kN to 10 kN and further increase to 9.0 kN and 11.1 kN, respectively. A displacement towards the ploughed field from 0 to 10 cm increases it to 11.25 kN and 17.25 kN, respectively.

Changing this parameter from 10 cm to 15 cm increases the depth of plant residue placement from 5 cm to 13.75 cm, and from 15 to 20 cm it decreases to 13.25 cm.

The transverse and longitudinal distances in plan from the toe of the ploughshare to the center of the disk skim-coulter have an interdependent effect on the clogging of the working parts of the plough. Its minimum value was obtained at $b = -8$ cm and $l = 20$ cm.

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