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DEFINITION DRIVE RESISTANCE OF THE HULL PLOW WITH UNDER-CUT FORMATION

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Annotation. The article presents the results of a theoretical study of the determination of the traction resistance of the plow body when the formation is undercut. The influence of the undercut width of the formation on the energy performance of the plow and the traction resistance of the hull is studied, taking into account the width of the undercut of the formation. According to the results of the research, it was found that the traction resistance of the body depends on the width and thickness of the processed layer, the width of its undercut, the angles of the plowshare to the bottom and the wall of the furrow, the thickness of its blade, the speed of the unit and the physical and mechanical properties of the soil.

Key words. Undercut of the formation, soil, traction resistance, physical and mechanical properties of the soil, angle of inclination, wrapping, plowshare blades, completeness and depth of embedding, plant residues, weed.

Introduction. The experience of leading foreign firms producing soil-cultivating machines and tools, as well as studies, show [1,2] that one of the most effective ways to reduce the energy intensity of plowing is undercutting the soil layers along

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their width by plow bodies, i.e. execution of the width of their capture of the plowshare is less than the width of the layer.

Proceeding from the foregoing, the purpose of this work is to study the influence of the undercut of the formation in width on the performance of the plow.

As is known [3], the turnover of the reservoir mainly depends on its size (thickness and width), the shape of the dump surface, the speed of the arable unit, and the physical and mechanical properties of the soil. In order to ensure complete and deep incorporation of plant residues, weeds and their seeds, as well as the unity of the arable land surface, the rotation of the layer should be as complete as possible. This requirement applies without exception to all types of plows.

Let us consider the influence of undercut of the seam in width on its turnover. Most of the existing plows, on the contrary, have overlapping bodies, for which the width of the plowshares of the bodies is made somewhat larger than the estimated width of the formation. It provides cutting of the layer across the entire width in case of sidewalling and curvilinear movement of the plow, but leads to an increase in its traction resistance.

The total traction resistance of the plow body is the sum of the resistance of its plowshare, blade and field board. However, the analytical determination of the traction resistance of the moldboard surface of the hull is very difficult. In addition, according to G.I.Sineokov and L.D.Turaev [4,5], the total traction resistance of the plowshare and the field board is more than 90% of the total traction resistance of the hull. It should also be noted that the presence of an undercut of the formation has a significant effect mainly on the traction resistance of the plowshare. In this regard, we have adopted the assumption that the traction resistance of the hull is considered as the total resistance of the plowshare and the field board (Fig.1).

$$R_к = R_л + R_п, \qquad (1)$$

where, $R_к$ - total traction resistance of the hull;

$R_л$, $R_п$ - respectively, the traction resistance of the plowshare and the field board of the hull.

The traction resistance of the body plowshare can be determined from the dependence [4,6,7]

$$R_л = R_1 + R_2 + R_3 + R_4, \quad (2)$$

where, R_1 - resistance of the soil to the introduction of the blade of the plowshare;

R_2 - soil resistance to deformation (shear);

R_3 - resistance due to movement and lifting layer of soil along the plowshare;

R_4 - resistance due to the inertial force of the soil layer.

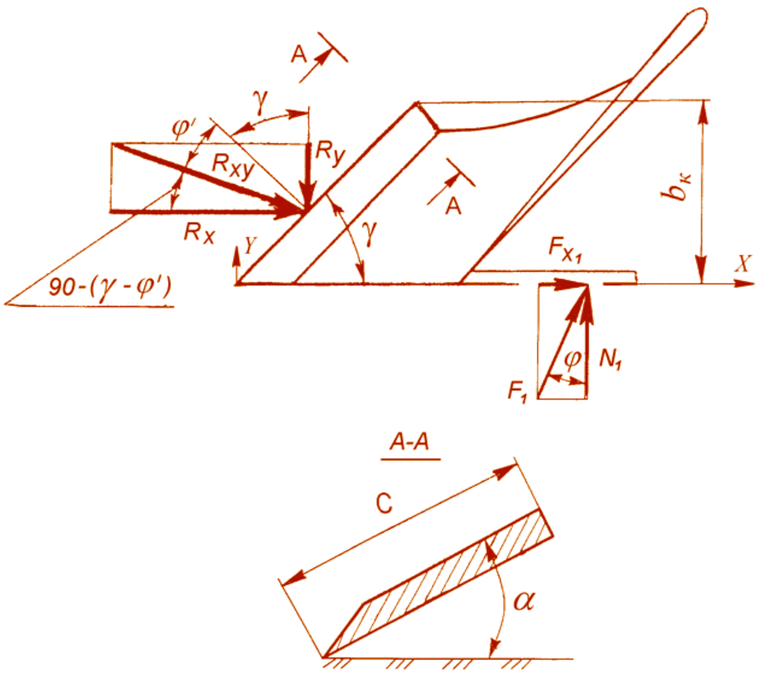

Fig.1. Forces acting on the plow body

Soil resistance to the penetration of the share blade can be determined by the formula [6]

$$R_1 = K_1\, T\, t_л\, b_л\,, \quad (3)$$

where, K_1 - coefficient taking into account the shape of the front surface of the share blade (for a straight blade K1=1);

T - soil hardness;

$t_л$, $b_л$ - respectively, the thickness and length of the share blade.

From the scheme shown in Fig. 2, it follows that $b_л = (b - \Delta b)/\sin\gamma$. C given this expression (3) has the following form $R_1 = K_1\, T\, t_л\, (b-\Delta b) / \sin\gamma$. (4)

The resistance of the soil to deformation can be determined by projecting the shear force S (Fig. 1) and the friction force arising from this force onto the X axis, i.e.

$$R_2 = S[\cos\psi + f\sin(\alpha+\psi)\cos\alpha]\sin\gamma, \quad (5)$$

where f - coefficient of friction of soil on metal.

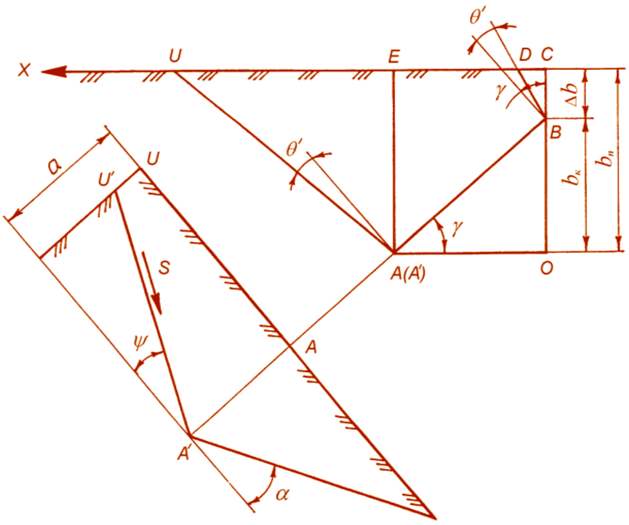

Fig.2. Scheme for determining the resistance of soil deformation

Bearing in mind that $S = \tau F$ (where τ - soil resistivity to shear; F is the area of the plane along which the shift of the soil layer occurs), we will rewrite expression (5) in the following form

$$R_2 = \tau F[\cos\psi + f\sin(\alpha+\psi)\cos\alpha]\sin\gamma. \quad (6)$$

Using the scheme shown in Fig. 2, we determine the area of the shear plane of the soil layer. Assuming that the shear plane reaches the surface of the furrow wall [1], we obtain

$$F = \frac{F_{ABDU}}{\cos\psi}; \quad (7)$$

$$F_{ABDU} = F_{AEU} + F_{ABCE} - F_{BCD}; \quad (8)$$

$$F_{AEU} = \frac{1}{2}b_n^2 tg(\gamma+\theta'); \quad (9)$$

$$F_{ABCE} = \frac{1}{2}(b_n^2 - \Delta b^2) ctg\gamma; \qquad (10)$$

$$F_{BCD} = \frac{1}{2}\Delta b^2 tg(\gamma - \theta'). \qquad (11)$$

Taking into account formulas (7)…(11), and also that $\theta' = arctg\frac{tg\theta}{\cos\psi}$,

$\psi = \frac{\pi}{2} - \frac{1}{2}(\alpha + \varphi_1 + \varphi_2)$ и $\theta = \frac{\pi}{4} - \frac{\varphi_2}{2}$ expression takes the following form

$$R_2 = \frac{1}{2}\tau\left[\sin\frac{1}{2}(\alpha + \varphi_1 + \varphi_2) + f\cos(\alpha - \varphi_1 - \varphi_2)\cdot\cos\alpha\right]\times$$
$$\times\frac{\sin\gamma}{\sin\frac{1}{2}(\alpha+\varphi_1+\varphi_2)}\left\{b_n^2\left[tg\left(\gamma + arctg\frac{tg\left(\frac{\pi}{4}-\frac{\varphi_2}{2}\right)}{\sin\frac{1}{2}\left(\alpha+\varphi_1+\varphi_2\right)}\right)+ctg\gamma\right]-\right.$$
$$\left.-\Delta b^2\left[tg\left(\gamma - arctg\frac{tg\left(\frac{\pi}{4}+\frac{\varphi_2}{2}\right)}{\sin\frac{1}{2}\left(\alpha+\varphi_1+\varphi_2\right)}\right)+ctg\gamma\right]\right\}. \qquad (12)$$

The resistance due to the movement and rise of the soil layer, taking into account the width of its undercut, can be determined by the formula [7]

$$R_3 = c\rho g\left[ab_n - 0{,}5\kappa\Delta b^2(2-\kappa)tg\,\psi_б\right]\frac{\cos^2\alpha\sin(\alpha_1+\varphi_1)}{\sin\gamma\cos\varphi_1}, \qquad (13)$$

where ρ - soil density;

g - acceleration of gravity;

c - share width; $\alpha_1 = arctg(tg\alpha\sin\gamma)$.

The resistance arising from the inertia force of the formation, taking into account the width of its undercut, is determined by the formula [7]

$$R_4 = 2\rho\left[ab - 0{,}5\kappa\Delta b^2(2-\kappa)tg\,\psi_б\right]V^2\frac{\sin\alpha_1\sin\gamma\sin(\alpha_1+\varphi_1)}{\cos\varphi_1}, \qquad (14)$$

where V - the speed of the arable unit.

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The traction resistance of the field board of the hull is determined from the condition of equilibrium of the projection of the forces acting on the hull onto the axis *Y* (fig.1)

$$\sum Y = 0; \qquad -Ry + N = 0. \tag{15}$$

G.N.Sineokov [3] determines the value R_y by known value R_x,

$$R_y = R_x ctg(\gamma + \varphi'), \tag{16}$$

where

$$\varphi' = arctg \frac{tg\varphi_1 \cos\gamma}{\sin\alpha + tg\varphi_1 \sin\gamma \cos\alpha} . \tag{17}$$

Taking into account (15) and (16)

$$R_n = fN = fR_x ctg(\gamma + \varphi') = fR_л ctg(\gamma + \varphi') . \tag{18}$$

Substituting the values of R_1, R_2, R_3 и R_4 first in (6) and (18), received values $R_л$ и R_n в (1), we have

$$R_к = \frac{1}{\sin\gamma} K_1 T t_л (b_n - \Delta b) + \frac{1}{2}\tau \times$$

$$\times \left[\sin\frac{1}{2}(\alpha + \varphi_1 + \varphi_2) + f\cos(\alpha - \varphi_1 - \varphi_2)\cdot\cos\alpha \right] \times$$

$$\times \frac{\sin\gamma}{\sin\frac{1}{2}(\alpha + \varphi_1 + \varphi_2)} \left\{ b_n^2 \left[tg\left(\gamma + arctg \frac{tg\left(\frac{\pi}{4} - \frac{\varphi_2}{2}\right)}{\sin\frac{1}{2}\left(\alpha + \varphi_1 + \varphi_2\right)} \right) + ctg\gamma \right] - \right.$$

$$\left. - \Delta b^2 \left[tg\left(\gamma - arctg \frac{tg\left(\frac{\pi}{4} + \frac{\varphi_2}{2}\right)}{\sin\frac{1}{2}\left(\alpha + \varphi_1 + \varphi_2\right)} \right) + ctg\gamma \right] \right\} +$$

$$+ \rho\left(gc\frac{\cos^2\alpha}{\sin\gamma} + 2V^2 \sin\alpha_1 \sin\gamma \right)\left[ab_n - 0{,}5\kappa\Delta b^2 (2-\kappa) tg\psi_б \right] \times$$

$$\times \frac{\sin(\alpha_1 + \varphi_1)}{\cos\varphi_1}\left[1 + fctg(\gamma + \varphi') \right]. \tag{19}$$

From the analysis of this expression, it follows that the traction resistance of the body depends on the width and thickness of the processed layer, the width of its undercut, the angles of installation of the plowshare to the bottom and wall of the furrow, the thickness of its blade, the speed of the unit and the physical and mechanical properties of the soil.

Calculations carried out according to the formula (19) at $K_1 = 1$; $t_л = 0{,}002$ м; $T = 5{\cdot}10^6$Pa; $\tau = 32{,}5{\cdot}10^3$Pa; $\alpha = 30^o$; $\gamma = 40^o$; f=0,70; $\varphi_1 = 35^o$; $\varphi_2 = 40^o$; $\rho = 1400$ kgг/m^3; $c = 0{,}14$ m; $V = 2$ m/s; $\psi_б = 35^o$ [1,3,8,9] showed that with an allowable undercut width ((Δb = 10 cm), the traction resistance of the hull decreases by 15 ... 16%.

Conclusion.

1. The conducted studies have shown that in order to reduce the energy intensity of plowing and improve the turnover of the layer and the quality of incorporation of plant residues and weeds, the plow bodies on the plow frame should be installed with undercutting of the layers in width, i.e., the width of the body should be less than the width of the plow processed by it soil layer.
2. The traction resistance of the body depends on the width and thickness of the processed layer, the width of its undercut, the angles of installation of the plowshare to the bottom and wall of the furrow, the thickness of its blade, the speed of the unit and the physical and mechanical properties of the soil.
3. The undercutting of the layer in width within acceptable limits leads to a decrease in the traction resistance of the plow body by 15 ... 16%.
4. Equipped with bodies that act on seams with the recommended undercut width and have recommended parameters, in comparison with the base one, it provides a better quality of plant residues incorporation with less traction resistance.

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