

Influence Of An Attack Angle Of A Spherical Disk Suggests And The Progressive Unit Speed On The Distance Of Soil

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Abstract -The article discusses the theoretical and experimental substantiation of the range of discarding the soil cut by a spherical skimmer. Given that the rotation of the disk occurs due to exposure to soil and particles. The influence of the disk attack angle (α) and translational speed (V_m) of movement on the throwing distance was determined when installing the disk skimmer so that the diametrical section of the plane of its blade was a longitudinally vertical plane (longitudinal with respect to the direction of movement) located in plan on the line of movement of the field edge of the body

To prevent plow clogging with plant debris, the option of combining a spherical disk as a skimmer was selected. Theoretically and experimentally substantiated the technological process of working the plow with a skimmer in the form of a spherical disk, the radius of the sphere $r = 0,6$ m, the stroke depth $h_1 = 0,13$ m, the radius of the disk $R = 0,325$ m and the translational speed of the plow $1,7-2,7$ m/s.

Keywords -soil, mass, particle, disk, width, depth, angle, rotation, speed, rejection, plowing, bottom hole, range of rejection, movement, angle of attack.

Introduction

Currently, in our Republic about 1 million hectares of irrigated land is sown with grain. On these lands, after harvesting, a significant amount of plant mass remains in the form of stubble and straw. When plowing them, existing plows are often clogged and, as a result, the quality of arable land deteriorates, the productivity of arable units decreases due to the time required to eliminate the faces. To avoid this, farms plow the fields under grain with removed skimmers or upper bodies, which significantly worsens the completeness and depth of embedding plant debris or burn them before plowing causing great harm to the soil, microorganisms and the environment, while high-quality plowing of plant debris leads due to anaerobic rotting to improve the structure of the soil [1].

It follows from the foregoing that studies aimed at substantiating the parameters of a plow for plowing fields with a significant amount of crop residues of crops, ensuring their complete and deep incorporation into the soil without bottom faces, are relevant and have great economic value [2-4].

To date, the question of eliminating the faces of plows has been studied by many researchers, as a result of which the directions that contribute to solving this issue have been identified. Basically, the problem was solved by removing the racks from the field edge of the buildings towards the plowed field, removing them from under the plane of the frame and installing additional working bodies. However, this issue was not completely resolved, and when plowing fields with a significant amount of plant residues and weeds on the surface, the existing plows become clogged, which worsens the quality indicators of their work and reduces productivity due to the time spent on cleaning the working bodies [5].

The technological process of working a reversible plow with a spherical disk skimmer and fairings mounted on the field edge of the left and right-handed buildings, dump surfaces of which are interconnected, is as follows. The plant debris on the soil surface and the roots in the upper layers of the formation are cut by a spherical disk skimmer and, together with the upper soil layer, are discharged into the furrow formed by the previous building, clearing the path of the field cutoff of the subsequent building from the fairing mounted on it. The roots that are raised along the field edge from the lower layers of the formation fall on the fairing, which eliminates their breakage and helps the broken off roots to slip off of the part of the field edge located below the fairing.

Research Methods.

A disk skimmer cuts off a layer of soil during operation, which moves along its spherical surface. With external sharpening of the disk, the end point of vanishing from its spherical surface will be on the edge of the edge of the blade, and with internal at a certain distance from it, due to the plane of the chamfer of the blade located on the side of the working surface, i.e. the actual radius of the working surface of the spherical disk in the second case will be less. Consequently, the range of soil rejection, ceteris paribus, disks with external and internal sharpening, will be different.

The use of a spherical disk as a skimmer determines the need to determine the throwing distance of the soil cut by it, since plant debris and weeds with it must be moved to the open bottom of the furrow formed by the previous plow body. Therefore, the throwing distance (y) is limited by the following condition (Fig. 1) [6-9]

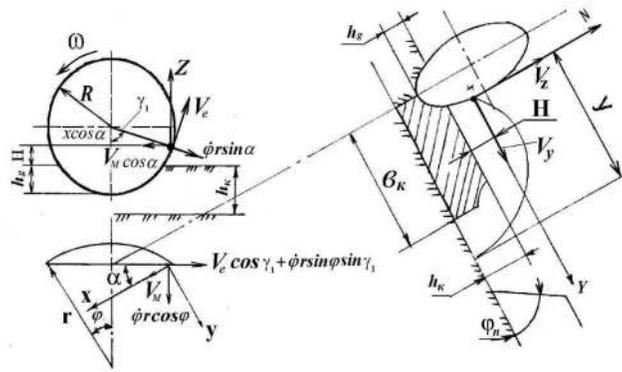


Fig. 1. The scheme for determining the range of discarding soil particles

$$2b_k + h_k - \frac{kh_k \text{ctg } \varphi_n}{2} \geq y \geq b_k - R \sin \gamma_1 \sin \alpha, \quad (1)$$

where b_k - is the width of the plow body, m;

h_k - plow body stroke depth, m;

k - is the coefficient of fluffiness of the soil;

φ_n - is the angle of repose of the soil, deg;

α - angle of movement of soil particles along the disk, deg.

From Fig. 1 we have

$$y = V_y \frac{V_z + \sqrt{V_z^2 + 2(H + h_k)g}}{2g}; \quad (2)$$

$$H = R(1 - \cos \gamma_1) - h_1; \quad (3)$$

$$V_y = \dot{\varphi} r [\sin \varphi \cos \alpha + \cos \varphi \sin \alpha \cos \gamma_1] - V_e \sin \alpha \cos \gamma_1; \quad (4)$$

$$V_z = V_e \sin \gamma_1 - \dot{\varphi} r \sin \varphi \cos \gamma_1; \quad (5)$$

$$V_e = V_M \cos \alpha; \quad (6)$$

$$\gamma_1 = \omega t_1, \quad (7)$$

где V_z, V_y - projection on the coordinate axis of the absolute velocity of the descent of the soil particles from the disk, m/c;

H - he height of the descent of the soil particles from the disk, m;

g - acceleration of gravity, m/s².

t_1 - time of movement of a soil particle along the working surface of the disk, s;

V_M - translational speed of the arable unit, m/s;

$\dot{\varphi}$ - the angular velocity of the particle at the moment of descent from the working surface of the disk, c-1.

Considering that the rotation of the disk occurs due to the effect of soil on it and the particles supported by its flow move mainly in the radial direction, we compose the equation of the relative motion of the particle to determine its angular velocity ($\dot{\varphi}$) at the moment (t_1) of descent from the working surface of the disk and time (t_1) interactions with the latter (Fig. 2).

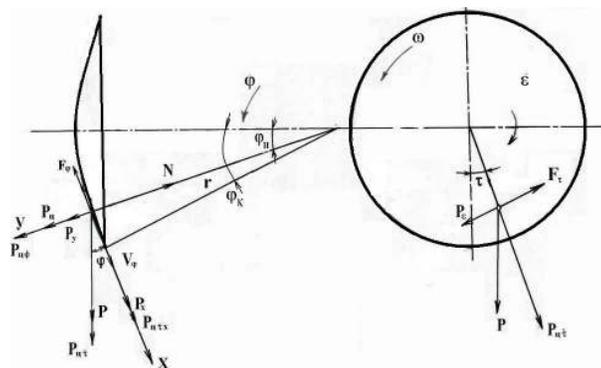


Fig. 2. Scheme of forces acting on a soil particle

$$mr\ddot{\varphi} = P \cos \varphi + P_{u\tau} \cos \varphi - F_{TP} \sin \psi, \quad (8)$$

where m – is the particle mass, kg;

$$P = mg \quad - \text{gravity, H;}$$

$P_{u\tau} = m(\dot{\tau})^2 r \sin \varphi$ - centrifugal inertia force arising from the portable rotational movement of the disk with an angular velocity “ τ ”, H;

$$F_{TP} = fN \quad - \text{friction force, H;}$$

f - is the coefficient of friction of the soil on the disk material;

$$N = P_{u\varphi} + P \sin \varphi + P_{u\tau} \sin \varphi \quad - \text{normal reaction of the working surface of the disk to the particle, H;}$$

$P_{u\varphi} = m(\dot{\varphi})^2 r$ -centrifugal inertia force arising from the angular displacement of a particle around the center of a sphere with an angular velocity $\dot{\varphi}$, H;

$$\sin \psi = \frac{\dot{\varphi}}{\sqrt{\dot{\varphi}^2 + \omega^2 \sin \varphi}}. \quad (9)$$

After substitutions and transformations, equation (8) takes the following form

$$\ddot{\varphi} = \frac{g \cos \varphi}{r} + \frac{\omega^2 \sin 2\varphi}{2} - f \frac{\dot{\varphi}}{\sqrt{\dot{\varphi}^2 + \omega^2 \sin 2\varphi}} \times \left(\dot{\varphi}^2 + \frac{g \sin \varphi}{r} + \omega^2 \sin^2 \varphi \right) \quad (10)$$

Equation (10) is a second-order non-linear inhomogeneous equation describing the relative movement of a particle along the rough surface of a spherical disk, the solution of which is not possible by the analytical method, therefore it is solved numerically, in particular, the Runge-Kutta method was applied. When solving the equation, the initial conditions were as follows

$$\varphi_{ii} = \arcsin \frac{R - h_1}{r}; \quad \omega = \frac{V_M \cos \alpha}{R}; \quad \dot{\varphi} = 0.$$

Calculations showed that to fulfill condition (1) with rational values $h_1=14,5$ sm, $R=34$ sm and plow speeds within $V_M = 2,4 \dots 3,0$ m/s, the radius of the sphere should be $r = 0,6$ m.

Results.

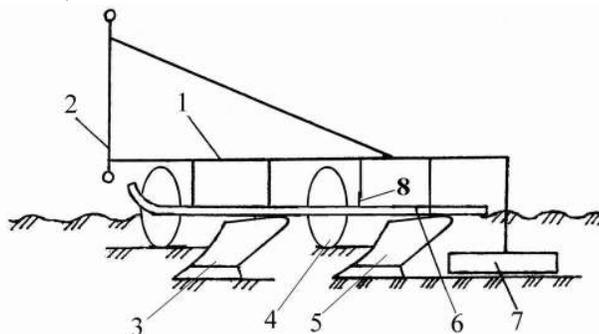
Calculations showed that for $h_g=13$ sm, $\alpha=400$, and disc parameters from disc harrow ($r = 60$ sm, $R=32,5$ sm), to fulfill condition (1), the translational speed of the plow must be more than 2,64 m/s, but not exceed 3,33 m/s. In the calculations, the coefficient of fluffiness was assumed to be $K = 1,3$, the angle of repose of the soil was $\varphi_n = 380$, the depth of the hike $V_k=45$ sm, and its capture width. Taking rational values $h_g=14,5$ sm, $R=32,5$ sm and the same values of the remaining factors ($r, h_k, V_k, \varphi_n, K, \alpha$)

$$Y_1 = y + R \sin \gamma_1 \sin \alpha, \quad (11)$$

equal to the middle part of the constraint (1), it will satisfy it (1), as at the speed of the plow, within $V = 2,5 \dots 3,23$ m/s, and at a speed of 3,0 m/s, in the range of radius spheres $r = 0.5 \dots 1.0$ m.

In order to verify the results of theoretical studies, an experimental study was conducted.

Experimental studies were carried out according to TSt 63.02.2001 "Tests of agricultural machinery. Machines and implements for deep tillage. Program and test methods" [10-12] using a field strain gauge installation, on which you can determine the traction resistance of both the main body and the skimmer (in our case, disk). The installation allows (Fig. 3) to change, within the necessary limits, the relative position of the main body and the disk skimmer (hereinafter referred to as the disk) in both longitudinal and transverse and vertical directions, the angle of attack of the disk (the angle between the line of the blade of the disk in the plan and directions of movement).



1 - frame; 2 - hitch; 3 - plow body; 4 - strain gauge disk; 5 - strain gauge plow body; 6 - ski; 7 - field board; 8 - strain gauge disk;

Fig. 3. Field strain gauge installation

The casting distance of the soil with a disk skimmer was determined by laying checkers in the surface soil layer, so that they were visible on the surface of the field for the purpose of oriented movement of the tractor with a laboratory-field setting during experiments. The experiments were carried out with the previous housing relative to the disk skimmer, to open the furrow, but without the subsequent one, in order to exclude the possible distortion of the result by the last soil moved by the soil. After the passage of the installation, the throwing distance of the checkers relative to the furrow wall from the previous building was measured.

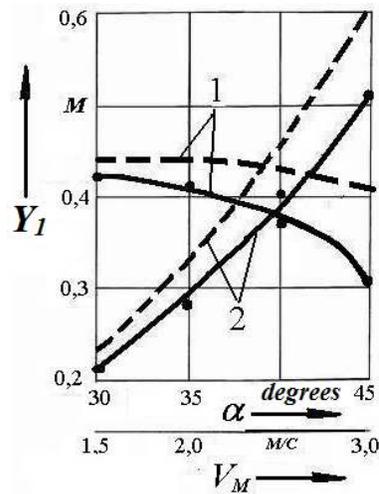
The influence of the disk attack angle (α) and translational speed (V_m) of movement on the throwing distance was determined when installing the disk skimmer so that the diametrical section of the plane of its blade was a longitudinally vertical plane (longitudinal with respect to the direction of movement) located in plan on the line of movement of the field edge of the body. Therefore, the range of the garbage was determined by the distance at which the checker is located from the furrow wall of the subsequent building in terms of the formula

$$Y_1 = Y_2 + b_k \quad (12)$$

where Y_2 is the distance to the discarded checkers against the furrow walls of the previous building.

The research results are shown in Fig. 4, from which it can be seen that with an increase in the angle α from 300 to 400, the throwing range (Y_1) of the checker decreases by 5 sm. A further increase in α to 450 leads to an increase in the intensity of decreasing the throwing distance, i.e. with an increase in α by 50 from 400 to 450, the throwing distance (Y_1) decreases by 7,5 sm. This is explained by the fact that with an increase in α the rotation speed of the disk theoretically decreases, and in the range $\alpha = 400 \dots 450$ due to the increase in the slip of the disk along soil it decreases more intensively. In addition, the angle between the absolute velocity vector of the soil at the moment of descent from the working surface of the disk and the direction of movement of the arable unit in the plan is reduced.

It can also be seen from Fig. 4 that with an increase in translational speed, the range of soil dropping increases, this is explained by an increase in the speed of rotation of the disk and, therefore, the absolute speed of soil dropping at the moment the latter leaves the working surface of the disk.



1- $Y_1 = f(\alpha)$ $V=2,4$ m/s; 2- $Y_1 = f(V)$ $\alpha = 40$
 At $R = 0,325$ m; $h_g = 0,15$ m; $r = 0,6$ m; $f = 0,57$

Fig. 4. The dependence of the throwing distance (Y_1) of a soil particle from the angle (α) of the disk attack and the speed (V_m) of plowing.

A comparison of experimental and theoretical curves (Fig. 4) shows the identity of their nature. The difference in the values of the casting distance obtained experimentally from the calculated ones is explained by the fact that theoretical studies did not take into account the adhesive adhesion of the soil to the working surface of the disk, the presence of which changes both the magnitude and the direction of the absolute rate of descent of the soil particle from it.

Conclusions.

The strength of adhesive adhesion is directly proportional to the pressure of the soil, which explains the increase in the difference with an increase in the angle of attack (α) of the disk attack and speed (V_m) of movement, since this increases the normal pressure of the soil on the working surface of the disk.

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