Justification of the parameters of the disc plough

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Abstract. Tillage is one of the most energy-intensive processes. Therefore, it is important to develop energy-efficient and resource-efficient, as well as high-performance disc plough. Based on this, a disk plough was developed and its parameters were researched. According to results of theoretical research, to ensure quality tillage, disc plow should be equipped with discs with a diameter of 65 cm and a radius of curvature of 70 cm, and they should be installed at least 38 and 17 angles respectively, relative to direction of movement and verticality.

1. Introduction
Wheat is one of the main and important crops in Uzbekistan [1, 2]. In Uzbekistan, due to limited land resources, after harvesting wheat [3], it is replaced by corn, soybeans [4], from which fodder for livestock [5, 6] and additional grains [7, 8], potatoes and vegetables and additional food is obtained. It also increases the income of farms. However, after wheat, remnants of wheat stalks in field and decrease and hardening of soil moisture do not allow it to be prepared with quality equipment and technologies, preparing the soil for quality planting [9, 10, 11, 12].

Land can be cultivated after irrigation, but during this period in Uzbekistan it is difficult to irrigate due to lack of water and increases water consumption [13, 14]. According to results of study of the working process of the existing plows, it was found that disc plows are acceptable when cultivating fields emptied of wheat for replanting.

In recent years, plough in form of spherical discs are widely used in the world for tillaging. Because disc work tools are not only forward-moving, but also rotary-acting, disc-ploughs have less resistance to gravity than overturned ploughs, and operate without clogging with weeds and plant debris. In addition, disc ploughs are simpler in structure than tilting ploughs, requiring fewer repairs and maintenances.

Because their cutting blades are less worn and constantly self-sharpening (due to rotation) and length (relative to the blades of lemexes), the discs last several times longer than lemexes [15]. A number of scientists have been involved in the study of disk work bodies and plugs. When R.J. Godwin and others studied discs with a diameter of 610 mm and a radius of curvature of 700 and 1400 mm in the United States by varying the mounting angle relative to the direction of motion from 20 ° to 30 °, the traction resistance was lower when the discs were set at 20-22 ° [16]. H. Harrison found that mounting angle of the discs ranged from 30 ° to 45 ° and increasing speed would increase reaction of soil to disc from side. Md.Monjurul conducted research on the reaction
(resistance) strength of the soil to disk work tools [17]. El-Shazly and others found to be acceptable that in Egyptian conditions, mounting angle of the disc plough relative to direction of movement is 45 to 50°, mounting angle relative to vertical is 18-22 °, working speed is 6.3 km/h, plowing depth is around 15 cm. O.E.Omofunmi and others studied disk ploughs in Nigeria, N.Abdalla Osman, Li Xia, Zhang Dongxing in Sudan and China depending on physical and mechanical properties of soil, it was determined that in conditions of low soil moisture, at a working speed of 7 km/h, the resistance to gravity will be minimal, ensuring high-quality soil cultivation [19, 20].

M. Hann, J. Gissible, R. Manian, S. Bukhari and others have shown that performance of a disk plow depends more on speed of the disk, direction of movement of the disk and mounting angles relative to the vertical, and they should be 42-45 ° and 15-25 ° [21-23].

Abu Hamdeh and Reeder have suggested that reason for the increase in slip as angle of inversion increases may be due to an increase in tensile strength [24]. J. Arvidsson et. al. studied special tags for various plowshares, plowshares, and disc harrows [25]. The design of machining depth, working width, geometry and stability and forward movement speed was studied by Naderloo et al. [26]. Ch. Benard et al. conducted research on al bionic discs and convex bionic surfaces and studied the possibility of reducing the maximum resistance to a maximum of 19.5% to 9% reduction in maximum resistance [27-34].

2. Materials and methods

Based on the above, the Tashkent State Technical University conducted theoretical research on development of a disk plug and the substantiation of its parameters in accordance with the soil and climatic conditions of the Republic. This article presents the results of theoretical research in this area to substantiate the disc diameter and radius of curvature, direction of movement and installation angles relative to vertical of the disc plow to ensure quality tillage.

Theoretical mechanics and rules of higher mathematics were used in the theoretical determination of disk plow parameters. In doing so, piece of soil cut by the disk was taken as a particle, and its motion in a spherical disk in rotation was studied. It has also been determined that motion of a soil particle consists of a complex motion due to its rotation along disk and its forward motion along with the plow.

Based on these data, in accordance with STATE STANDARD 198-75 and taking into account, disk working tools used in the agricultural machinery of the Republic, diameter of the disk for use in developed disk plough was 65 cm and radius of curvature was 70 cm.

3. Results and discussion

We determine velocity of the soil from disk to side using scheme shown in Figure 1, and by the velocities.

\[ V_y = V_n^T (\sin \varphi_t \cos \alpha + \cos \varphi_t \sin \tau \sin \alpha) + V_k^T \cos \tau \sin \alpha \cos \beta, \]

there \( V_n^T \), \( V_k^T \) – relative and transfer velocities of soil fragments at the time of descent from the disk, \( m / s \); \( \varphi_t = \arcsin \frac{D}{2R} \) – half of the central angle of the arc formed in the diametrical section of the disc, degrees.

Expressing \( V_n^T \) and \( V_k^T \) by the parameters and speed of movement of the disk, we obtain the following final result.
Figure 1. Scheme for determining the speed of soil throwing from the disk to the side

\[
V_y = -\frac{1}{e^{\frac{2D}{\theta}}(1+4f^2)} \left[ \frac{6fgR}{(1+4f^2)} \cos(\varphi_0 + \beta) \cos \tau + 2gR \left( \frac{1-2f^2}{1+4f^2} \right) \times \right.
\]

\[
\times \sin(\varphi_0 + \beta) \cos \tau + 4V_n^2 \frac{R^2}{D^2} \cos^2 \alpha \left( \frac{\sin 2\varphi_0}{f} - \sin^2 \varphi_0 \right) \right] + \frac{6fgR}{(1+4f^2)} \cos \times
\]

\[
\times \left( \arcsin \frac{D}{2R} + \beta \right) \cos \tau + 2gR \left( \frac{1-2f^2}{1+4f^2} \right) \sin \left( \arcsin \frac{D}{2R} + \beta \right) \times
\]

\[
\times \cos \tau + 4V_n^2 \frac{R^2}{D^2} \cos^2 \alpha \left[ \frac{D}{fR^2} \frac{\sqrt{R^2-(0.5D)^2}}{R^2} - \left( \frac{D}{2R} \right)^2 \right] \right\} \left[ \frac{D}{2R} \cos \alpha \cos \beta +
\]

\[
+ \frac{\sqrt{R^2-(0.5D)^2}}{R} \sin \tau \sin \alpha \right] + 0.5V_n \cos \tau \sin 2\alpha \cos \beta
\] (2)

here \( g \) – is the acceleration of free fall, m/s\(^2\); \( f \) – the coefficient of friction of the soil on the working surface of the disc; \( \tau \) – the angle of rotation of the work tool relative to the vertical axis, degrees; \( \varphi_0 \) – half of the central angle, which determines the initial position of the piece of soil, degrees; \( R \) – radius of curvature of the disk work surface, m; \( D \) – diameter of the working tool, m; \( \alpha \) – is the mounting angle of the work tool relative to the direction of movement, \( \beta \) – is the angle of installation.
of the work tool relative to the vertical, degrees.

It can be seen from the expression that for the above condition, i.e., the working condition of soil throwing speed does not exceed 1.4 m/s, mainly correct choice of the direction of movement of discs and mounting angles relative to vertical, diameter, radius of curvature and speed account.

In Figure 2, graph of the change of $V_y$ in relation to $a$, $b$, $R$, $D$ and $V_n$ is constructed. It can be seen that increase in angles $\alpha$ and $\beta$ and $R$ leads to a decrease in $V_y$, and an increase in $D$ and $V_n$ leads to an increase in it.

![Graphs showing changes in $V_y$ with varying parameters](image)

**Figure 2.** We accept discs of change graphs in relation to $V_y$, $a$, $b$, $R$, $D$ and $V_n$. 
Data in Figure 2 show that for $Vy < 1.4 \text{ m/s}$ condition to be met and for plowing quality, the discs must be mounted at least 38 and 17° angles relative to direction of movement and vertical, respectively, with a diameter not exceeding 71 cm and a radius of curvature of 68 cm. not less than, and speed of movement should not exceed 2.2 m/s.

4. Conclusion

According to results of theoretical research, to ensure quality tillage, the disc plough should be equipped with discs with a diameter of 65 cm and a radius of curvature of 70 cm, and they should be installed at least 38 and 17 angles relative to direction of movement and verticality.

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