Ripper for processing slope fields

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Abstract. The purpose of the study is to substantiate the parameters of a spherical disk working body. New technology of tillage of slope fields that prevent water erosion, a design scheme of a ripper for its implementation is presented. The ripper consists of lower and upper working bodies of the "paraglider" type and a spherical disk. The study applied the laws and rules of theoretical mechanics, agricultural mechanics, mathematical statistics, and methods of strain measurement and the methods given in the existing regulatory documents (TSt 63.04.2001, TSt 63.03.2001). The new technology of tillage of slope fields makes it possible to form step ridges on the surface of the arable land and on the bottom of the furrow, which protects the soil of the slopes from water erosion. It is established that when the diameter of the spherical disk of 510 mm, the curvature radius of 56 mm, tilt angle relative to the direction of motion of 28-30° to the vertical at an angle of 17-18°, the transverse and longitudinal distance between the disc and work on the bottom ripper respectively 30 and 20 cm ensures the formation of ridges on the surface of the field according to agrotechnical requirements at a minimum cost of energy.

1 Introduction

Currently, the leading position is occupied by developing and implementing energy - and resource-saving, and highly efficient machines for tillage. If we consider that " 31% of the land is subject to water erosion, and 34% to wind erosion, and annually more than 60 billion tons "tons of fertile soil is washed into the world ocean" [5-6, 9, 17, 24-25, 27-30], then the development of energy - and resource-saving machines and tools that protect the soil from wind and water erosion is considered an important task.

In the world, research works are being conducted aimed at developing soil protection technologies for protecting the soil from wind and water erosion and technical means for their implementation [32-33]. It is relevant to conduct targeted scientific research on the development of dump and non-dump anti-erosion working bodies, ensuring resource

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conservation in the processes of their interaction with the soil.

Research on the development and application of machinery to protect the soil from water and wind erosion, in particular machinery working bodies of the "paraplu", studying their performance and justification of the parameters studied F.Mamatov [1-23], B.Mirzayev [4-12, 14-23] V.Alexandrian [28], A.Vagin [29], N.N.Nagorny [30], V.Svetlichniy [30], V.M.Drinca [32], D.A.Tryapitsyn [34], Pazova T [33], B.Borisenko [32] and others.

The machines and tools created as a result of these studies are used with certain positive results in the tillage of the slopes. However, these studies have not sufficiently studied the issues of substantiating the parameters of the disk working bodies of rippers that form ridges on the surface of the field to protect the soil from water erosion and ensure high quality of work with minimal energy costs [38-39].

The purpose of the study is to substantiate the parameters of a spherical disk working body.

2 Methods

The study applied the laws and rules of theoretical mechanics, agricultural mechanics, mathematical statistics, and methods of strain measurement and the methods given in the existing regulatory documents (TSt 63.04.2001, TSt 63.03.2001).

Analysis of studies has shown that the prevention of water erosion and increasing the degree of soil crumbling, as well as reducing fuel consumption, labor, and other costs when processing slope fields, can be achieved by using a ripper that forms ridges on the surface of the arable land and at the bottom of the furrow.
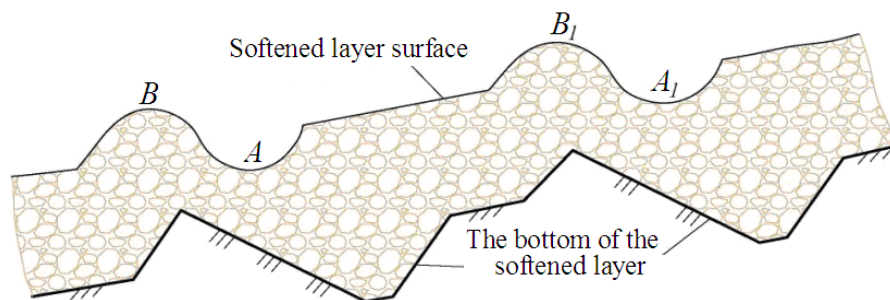

Fig. 1. Scheme of soil loosening technology and formation of ridges on slope fields: A, B, A_1, B_1 are grooves and ridges, respectively

The loosening of the soil and the formation of ridges are carried out on inclined fields simultaneously (Fig.1). The technology is carried out as follows: at first, the soil of the slope field is loosened in the form of steps without a fall. In this case, the bottom of the furrow of the loosened layer looks like in Fig.1. On the surface of the loosened layer, ridges B, B are formed due to the formation of grooves A, Ot. In this case, rain precipitation is absorbed into the loosened layer. Due to the different heights of the steps, the soil water does not flow down the slope.
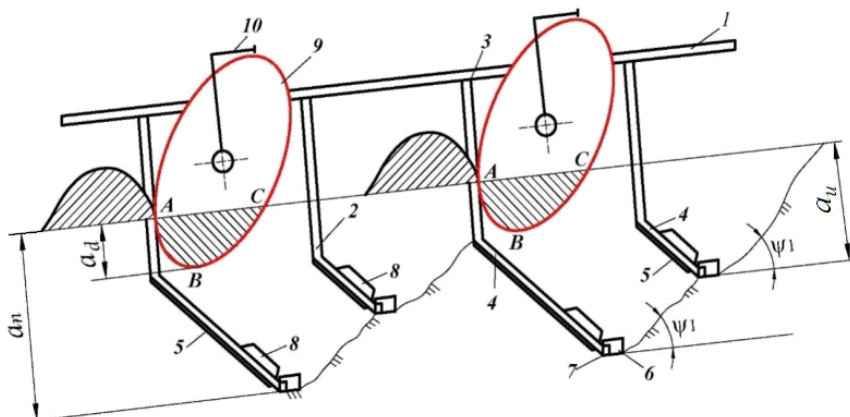
Fig. 2. Technological process of the ripper equipped with spherical disks: 1 is frame; 2, 3 are lower and upper rippers with an inclined rack; 4 are inclined ripper racks; 5 is knife; 6 are chisels; 7 is field board; 8 is plate; 9 is spherical disk; 10 is turning lever

A ripper scheme has been developed to implement the above technology, equipped with lower and upper ripping working bodies of the "paraglau" type and a spherical disk (Fig. 2). The slope of slope fields in the Republic, especially in the Kashkadarya region, is 3-12°. At the same time, the protection of the slope soil from water erosion depends on the parameters of the ridge

The ridge parameters, in addition to the slope of the field, depending on the amount of precipitation, their duration, and variety. In this regard, in the autumn months of 2017-2018, ridges of various cross-sectional areas and sizes were formed on the slope fields with the help of hand tools. These ridges were preserved in their natural form until the sowing works. Based on these studies, it was found that the cross-sectional area of the ridge is at least 97.5 cm^2.

The technological process of forming ridges in the direction of the slope of the slopes of agricultural fields according to agrotechnical requirements can be carried out by cutting out a layer of a certain cross-section and turning it in the direction of the slope.

For the formation of ridges and furrows on the surface of the arable land, a working body of the spherical disk type is selected. It is equipped with a turning mechanism. The spherical disk rotation mechanism parameters include the length of the handle OA=R, the length of the slot in the lever ln, and the length of the hydraulic cylinder rod AA2 (Fig 3).
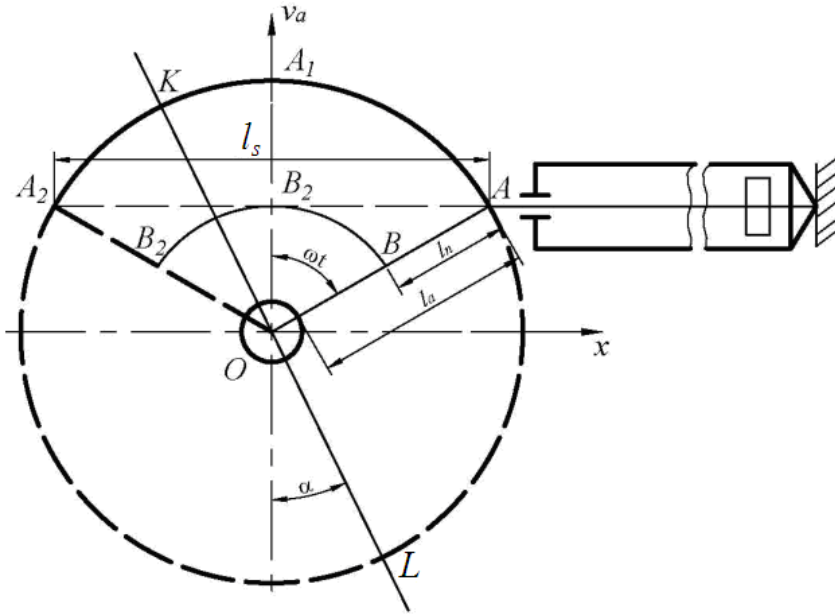
Fig. 3. Scheme for determining the parameters of the rotary mechanism

Considering that the disk rack is installed on the side of its working surface and the design features of attaching the rack to the frame, the length of the lever R is assumed to be 130 mm.

To move the spherical disk from the working position of the CL to the next one-A2, the lever must turn to position A1. From Fig. 3, the length of the AB slot in the lever is determined by the following expression

$$AB = R - R\cos\omega_t = R(1 - \cos\omega_t). \qquad (1)$$

Given that to move the lever to the final position of OA_2, it must rotate at an angle of $t = 50°-60°$ and $R = 130$ mm, we find $AB = 65$ mm. The length of the rod is determined from the triangle OAB 1: $l_s = 2AB$ $1 = 224$ mm. To implement the working process of this mechanism, a hydraulic cylinder C-40 was selected; its piston stroke is 250 mm.

The width of the formed ridge depends on the distance of the spherical disk throwing the soil particles in the transverse direction. The distance of the discarding of soil particles by a spherical disk is found by the following formula

$$X_y = \frac{v_a \cos(\alpha + \xi) \cdot \left[v_a \sin(\alpha + \xi) + \sqrt{v_a^2 \sin(\alpha + \xi) + 2gh_n} \right]}{g} \qquad (2)$$

where, v_a is the absolute velocity of the soil particles thrown by the spherical disk, m/s; a is the angle of the spherical disk to the direction of movement of the unit, degree; h_n is the difference of the horizontal planes formed by furrows and ridges based on the slope of the field, m. ξ is the central angle of the arc of the spherical disk, degree; g is the acceleration of gravity, m/s^2.

The range of transverse rejection of soil particles by a spherical disk can be determined by the following expression (Figure 4).
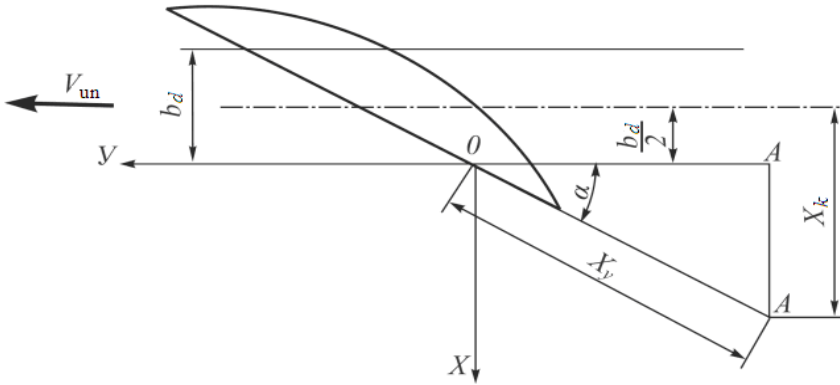
Fig. 4. Scheme for determining the range of transverse discarding of soil by a spherical disk

$$X_k = \left\{ \frac{v_a \cos(\alpha + \xi)\left[v_a \sin(\alpha + \xi) + \sqrt{v_a{}^2 \sin(\alpha + \xi) + 2gh_n}\right]}{g} \right\} \sin\alpha + \frac{b_d}{2}, \qquad (3)$$

From (3), we see that the range of cross drop of soil particles H_c depends on the absolute velocity of a spherical disc, the angle of incidence of the soil, slope fields, and the width of the disk.

Figure 5 shows graphs of the dependence of the cross-drop distance of the soil on the absolute velocity V_a and the angle of installation of the disk.
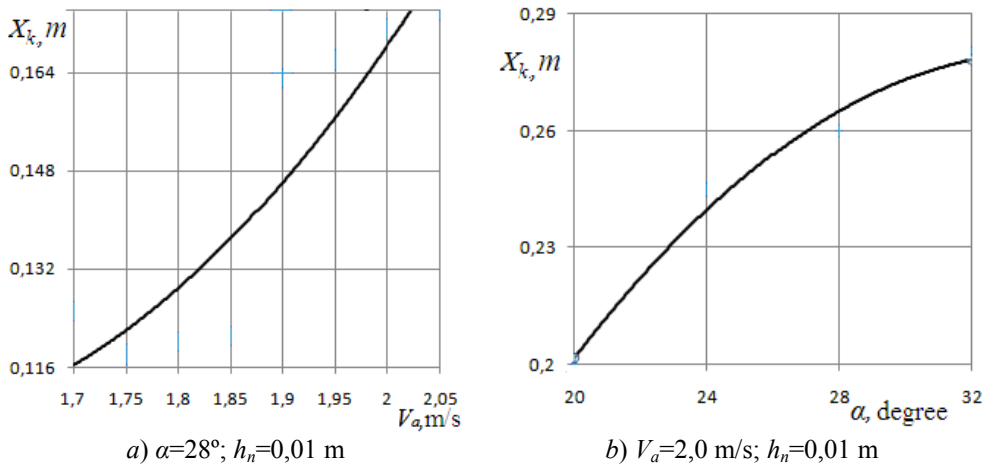

a) $\alpha = 28°$; $h_n = 0,01$ m   b) $V_a = 2,0$ m/s; $h_n = 0,01$ m

Fig. 5. Graphs of changes in H_c as a function of V_a, α, and h_p

The graphs analysis shows that to place the discarded soil particles along the axis of the formed ridge, the speed of movement of the spherical disk should be 1,75-25,05 m/s, and the installation angle should be within 28-30°.

The minimum transverse distance from the post of the lower ripper to the spherical disk was determined taking into account the zone of soil deformation of the bit of the upper ripper:

$$L_{kp} \geq b_{ki} + b_i + a_i ctg\,\psi_1 - b_k + \sqrt{R^2 - (R - a_d)^2}\,\sin\alpha. \qquad (4)$$

The calculations performed by expression (4) at b_k=35 cm, b_k=10 cm, b_i=6 cm, ψ_1=45°, R=25,5 cm, a_i=25 cm, and a_d=12 cm showed that at a transverse distance between the lower ripper stand and the spherical disk of at least 18 cm, their clogging with soil is excluded.

According to Fig.7, the longitudinal distance from the spherical disk to the lower ripper rack is determined by the following expression:

$$L_{bp} \geq \frac{2 \cdot [b_{kp} + b_i + a_i ctg\,\psi_1 - b_k + \sqrt{R^2 - (R - a_d)^2}\,\sin\alpha] - t_t}{2\cos(\alpha + \varphi)}, \qquad (5)$$

where tt is the thickness of the ripper stand, cm;
According to the formula (5), for L_{bp}=20-26 cm, t_t=5 cm, α=30° i_f=30°, the longitudinal distance between the lower ripper stand and the spherical disk should be at least 26 cm.
The minimum longitudinal distance from the upper ripper to the spherical disk is determined from the condition that the soil deformation zone treated with the upper ripper bit does not reach the structural elements of the spherical disk:

$$L_{bi} \geq b_t + H_{kt}\sin\beta_b + l_i\cos\alpha_i + a_i ctg\,\psi + \sqrt{R^2 - (R - a_d)^2}\,\cos\alpha \qquad (6)$$

where b_t is width stone burner ripper, cm; N_{kt} is the slant height of the rack, cm; l_i are length drill bits, cm; ψ is the angle of shearing the soil in the longitudinal direction, degree.
Calculations carried out according to expression (6) at b_i=200 mm, a_i=65°, φ=30°, N_{km}=0,20 m, β_b=25° showed that the longitudinal distance between the upper ripper rack and the spherical disk should be at least 33 cm.

3 Results and Discussion

In experimental research studied the effect of the scheme relative position of the working bodies on the frame, the transverse and longitudinal distances between the spherical disk and lowered the working body, parameters spherical disk, and the operating speed of the traction resistance of the cultivator, the degree of cracking of the soil and the height of the ridge, and in the second stage was conducted multivariate experiments with the use of mathematical planning of experiments.

According to the data of the conducted one-factor experiments, it was found that at speeds of 6-9 km/h to ensure the required quality of work and the height of the ridge with minimal energy consumption, the spherical disk should be installed at an angle of 28-30° to the direction of movement, the transverse and longitudinal distance between the disk and the lower ripper should be 30 and 20 cm, respectively.
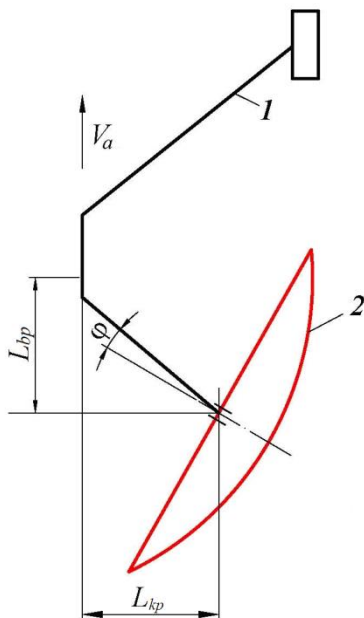
Fig. 6. Scheme for determining the longitudinal distance between the spherical disk and the lower ripper rack: 1 is the lower ripper; 2 is the spherical disk

According to the results obtained at speeds of 6-9 km/h to ensure the required quality of work with minimal energy consumption, the angle of installation of the spherical disk to the direction of movement should be within 28-30° and the transverse distance between the lower ripper and the spherical disk 18-20 cm. These results correspond to the results of theoretical studies.

4 Conclusions

1. The new technology of tillage of slope fields makes it possible to form step ridges on the surface of the arable land and the furrow's bottom.
2. The ripper's most optimal design scheme is considered a scheme consisting of upper and lower working bodies with inclined posts of the "paraglider" type and a ridge shaper of the spherical disk type.
3. With a diameter of a spherical disk of 510 mm, a radius of curvature of 56 mm, an angle of installation relative to the direction of movement of 28-30°, and to the vertical at an angle of 17-18°, the formation of ridges on the surface of the field is ensured following agricultural requirements with minimal energy consumption.
4. At the transverse and longitudinal distance between the disc working body and the lower ripper, respectively, 30 and 20 cm, the width and length of the field board, respectively, 7 and 18 cm, clogging of the working bodies with plant residues is excluded, high-quality loosening of the soil and stable movement of the ripper are ensured.

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