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Stepped plow with cutting disc for tillage of sloping fields

N Sh Rashidov[1], F M Maiviatov[1,2], L K Babajanov[3] and A Xujakulov[1]

[1]Karshi Engineering-Economics Institute, Karshi, Uzbekistan
[2]Karshi Institute of Irrigation and Agro technologies of the National Research University Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Karshi, Uzbekistan
[3]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers National Research University, Tashkent, Uzbekistan

*E-mail r.nargiza@mail.ru

Abstract. The aim of the research is to justify the design scheme and mutual arrangement of plough working elements for anti-erosion treatment of sloping fields. The authors have developed a stepped plough, which carries out beardless smooth plowing of sloping fields and formation of anti-erosion intermittent. The proposed technology firstly performs the turnover of layers within its own furrow, strip-tillage loosening of soil, then anti-erosion ridges and intermittent furrows with barriers of the arable land. Plough, carrying out this technology consists of stepwise located in the longitudinal direction of the right-harrowing screw bodies, skimmers, laughers and cut spherical discs that form on the surface of the arable anti-erosion ridges and pre-irrigated furrows with obstacles. The constructive scheme of offered plough. Parameters of spherical disk, mutual positioning of body, ploughing tool and spherical disk have been justified by theoretical investigations. For providing of the required quality of work diameter of the cut spherical disk should be within 420-510 cm, the angle of its installation 28-32º, minimum angle of sector of cut should be 49º, the depth of the sector not less than 10 cm, cut spherical disk even not less than 110 cm.

1. Introduction

Development of effective soil-protecting technologies of crops cultivation and technical means has a decisive importance in the complex of measures, ensuring soil protection from water erosion.

Development and slope fields subjected to water erosion and parts U. Kodirov [1, 15], E. Eshdavlatov [2], B.Mirzaev [3, 5, 10, 13], F.Mamatov [16-18], on the elements of plough S.Ochilov [19] on creation and application of linear-stepped ploughs for beardless smooth plowing, the study of their technological processes N.Aldoshin [20].

Researches questions on development linear-stepped plough with milled disc that enables to carry out the qualitative smooth thresh-less ploughing of hillside fields with simultaneous broken cultivated field, counteracting water erosion, have been studied insufficiently.

Research analysis has shown that it is possible to achieve prevention of water erosion during main tillage of hillside fields, reduction of fuel consumption, labour and material costs by applying technology of beardless smooth ploughing with simultaneous interrupted cultivated field and linear stepped plough for its implementation. Taking into account above-mentioned the linear-stepped plough with cutted disc was developed in Karshi Engineering and Economic Institute.

The purpose plough anti-erosion treatment of slope fields.

2. Materials and methods

The tillage of sloping fields without harrowing smooth plowing with simultaneous formation of anti-erosion intermittent arable, as well as of the plough were developed. A for was received for the offered plough.

In proposed technology in the beginning is carried out rotation of layers within own furrow, strip-till loosening of soil, then anti-erosion ridges and interrupted furrows with barriers are formed on arable surface (Figure 1).

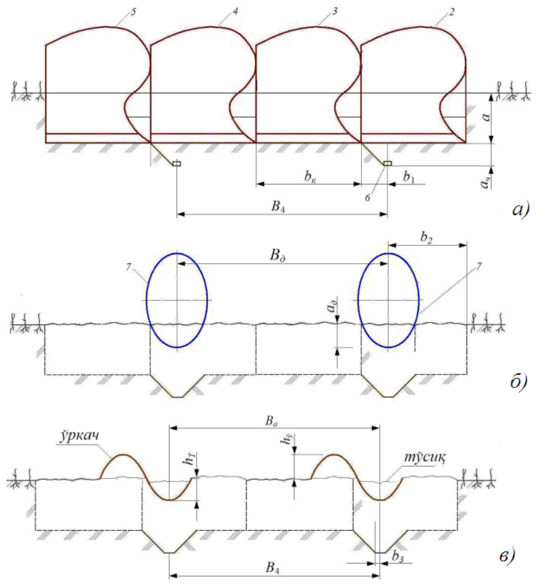

Figure 1. Technology of formation of anti-erosion discontinuous

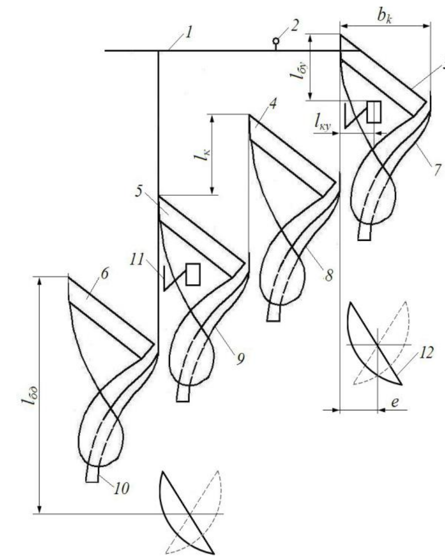

Figure 2. Constructive diagram and linear-stepped plough with cutting disk

Plough implementing this technology consists of frame 1, disc blades, stepwise located in longitudinal direction right turning screw bodies 3-6, skimmers 7-10, ploughs 11 and cutting discs 12 and 13. Ploughshares are fixed to ploughshare bodies, ploughshares of "Para plough" type to posts of odd bodies (Figure 2).

During operation of the plow disc blades 2 make vertical cuts of the field in the plane of the field cropping bodies and separate from an array of layers of width bn. Screw body 3 separates from the bottom layer with thickness a and width bn and together with plow 7 turns it within its own furrow. Simultaneously with the turnover of the layer odd body plow 11 performs loosening of the subsoil to a depth ah. Cutting disk 12, mounted after odd bodies, cuts the soil with thickness ah from arable surface and by turning around to the side of slope forms on arable surface anti-erosion ridges and intermittent furrows with barriers. After the plough's passage a stepped relief is formed at the bottom of the plough, and on its surface intermittent furrows are formed. All this contributes to the accumulation of water in the soil and protects it from being washed away by heavy rains.

The main parameters influencing quality indicators and traction resistance of linear-stepped plough are the following: longitudinal distance between bodies, width of bodies capture, place of ploughing plough body mounting, place of cutting discs mounting relative to bodies.

3. Results and discussion

Conducted analyses, it was found that when installing a spherical disc cutter behind odd-numbered bodies with soil tillers, the spherical disc cuts the soil from the upper part of the layer wrapped by odd-numbered body and falls off on the layer wrapped by even-numbered body. In this case, furrows are formed over the first layer, and under it loosened stepped profile. Ridges are formed over the layer, wrapped by even body, the soil of which contributes to full laying of the layer. At the same time, rainwater accumulated in the furrows are absorbed into the loosened subsoil layers.

The basic parameters of the spherical disc cut out are the following (Figure 3): disc diameter D; radius of curvature of working surface R; disc installation angle to movement direction α; sector angle of disc cut out part β; depth of disc cut out part h; blade installation angle of disc sector working part to its radius θ.

The diameter of the spherical disc cut out D is determined taking into account its working depth according to the following known expression

$$D \geq K a_{\kappa\partial}, \tag{1}$$

where K - coefficient, K=3.5-4; akd – depth of cultivation of spherical disk, cm.

At K=4 and depth of disk cultivation within 12-14 cm according to expression (1) we have D=420-510 mm, we take 460 mm.

In the course of work of a blade of a rib the sector of a cutting disk should cut the soil and the rests of plants. For this purpose, the rib must be sharpened and set at a certain angle to the disk radiator (Figure 4b). Taking into account the researches carried out earlier, we take the angle of sharpening of rib ic to be 15°. On the basis of our studies, it was found that when installing a sector rib along the radius or at an angle θ to the radial in the opposite direction of the disk rotation, pinching of cut materials by the sector rib and the ground surface of the field is ensured. To simplify the notch disk design, we take the sector rib along the notch disk radius, i.e. θ=0.

To determine the minimum angle of the sector of the cutting disc's sector, is of forming minimum permissible height of the obstacle in the furrow

$$\beta = \frac{h_m ctg\phi_\kappa \cos\alpha \cdot 360^0}{\lambda \pi R} \tag{2}$$

where φ_k – angle of soil collapse, °; h_t – height of the obstacle, cm; λ – index the kinematic mode of operation of the disc.

If (2) R=0.23 m, h_m=0.08 m, α=30°, φ_k=40° and λ=1 showed that the minimum sector angle is 49°.

The depth of the sector of the notch disk is determined taking into account the height of the obstacles formed in the grooves. Taking this into account, $h \geq h_t$. Taking into account that the minimum height should not be less than 8 cm, we take the depth of the sector to be 10.

Transversal cutting spherical disk shell to avoid particles of soil, wrapped by the front odd-shaped body, to get into the layer wrapped by the next odd-shaped body. On this basis we have

$$e > \frac{b_d}{2} + l_y - b_\kappa \tag{3}$$

where l_y – width of ridge formed on arable surface on the bottom part, m; b_d – width of disc capture, m.

From figure 5 we determined the following expressions for determining the distance of transverse throw of soil particles L_y and ridge height h_y:

$$L = ctg(\phi_m + \alpha_н)\sqrt{\frac{2\left\{\left(a_{\kappa\partial} - \frac{D \overleftrightarrow{}}{2}\right)\sqrt{a_{kd}(D - a_{kd})}\right) + \frac{D^2}{4}\left[arcsin\left(\frac{2a_{kd}}{D} - 1\right) + \frac{\pi}{2}\right]\right\} \sin\alpha}{ctg(\phi_m + \alpha_н) + ctg(\phi_m - \alpha_н)}} +$$

$$+ctg(\phi_m - \alpha_н)\sqrt{\frac{2\left\{\left(a_{kd} - \frac{D \overleftrightarrow{}}{2}\right)\sqrt{a_{kd}(D - a_{kd})}\right) + \frac{D^2}{4}\left[arcsin\left(\frac{2a_{kd}}{D} - 1\right) + \frac{\pi}{2}\right]\right\} \sin\alpha}{ctg(\phi_m + \alpha_н) + ctg(\phi_m - \alpha_н)}} \tag{4}$$

$$h_y = \sqrt{\frac{2\left\{\left(a_{kd} - \frac{D \overleftrightarrow{}}{2}\right)\sqrt{a_{kd}(D - a_{kd})}\right) + \frac{D^2}{4}\left[arcsin\left(\frac{2a_{kd}}{D} - 1\right) + \frac{\pi}{2}\right]\right\} \sin\alpha}{ctg(\phi_m + \alpha_н) + ctg(\phi_m - \alpha_н)}} \tag{5}$$

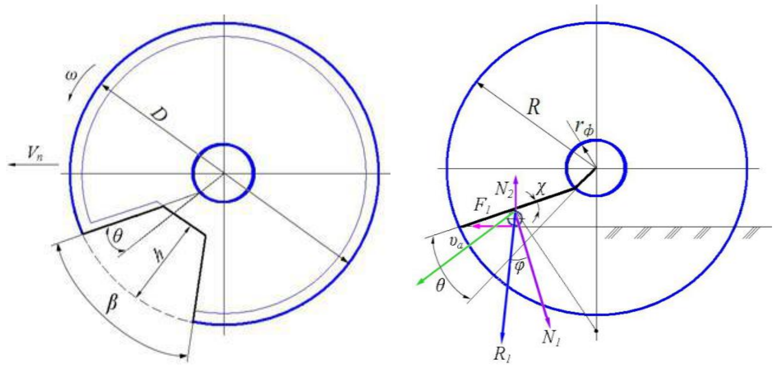

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Figure 3. Parameters of a cutout spherical disk

By expressions (4) and (5) at D=460 mm, a_{kd}=12 cm and $\varphi_k=\varphi_o=\varphi_o=40^o$, we determine the distance of the transverse rejection of soil particles Ly and the ridge h_y by the cut out spherical disk depending on different values of the slope of the slope field.

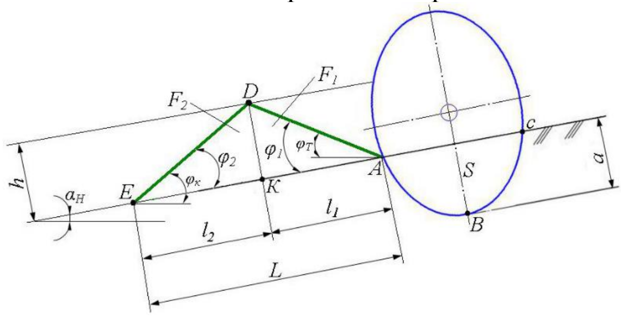

Figure 4. Schematic for determining the transverse throwing distance of soil particles L_y and ridge height h_y by a spherical cut-out disk

In figure 4, conditions according to expression (4) are completely fulfilled when installing the notch disc behind the odd-numbered body, so let's take

$$e \geq \frac{b_d}{2} = \frac{1}{2}\sqrt{a_{kd}(D - a_{kd})}\cos\alpha. \quad (6)$$

Calculations carried out according to expression (6) with a_{kd}=12 cm, α=300 and D=460 mm have shown, that the cross distance between the cut out spherical disk and the body should be not less than 8,8 cm. Taking into account the settings of the plough relative to the body and the cutting disc, we take e=15 cm.

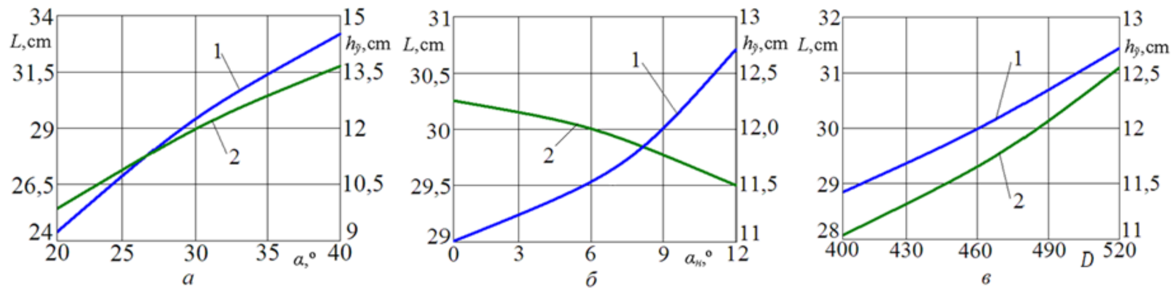

Figure 5. Plots of dependence of soil particles transverse ejection distance (L_y) and ridge height (h_y) on slope inclination angle (α_n), diameter of cut spherical disk (D) and angle of its installation to movement direction (α) at $\varphi_0=40^o$; a_{qd}=0,12 m

The even body cut out is overlap deformation by disk with layer turnover even body

$$L_{bd} \geq \mu a_k + \sqrt{R^2 - (R - a_{kd})^2}\cos\alpha + \{e +$$

$$+\left[\sqrt{R^2-(R-a_{kd})^2}\right]\sin\alpha\Big\}\ tg(\alpha+\phi_1). \quad (7)$$

where μ – is the coefficient characterizing the length of the layer turnover per its thickness; a_k – is the thickness of the layer, cm.

Analysis of the obtained expression even body notched there. Calculations made according to (7), at μ=4, a_c=24 cm, R_d=23 cm, a_{cd}=12 cm, α=30º, φ=25º and e=15 cm the even body cut-out 1.1 m.

4. Conclusions

The new anti-water erosion method of main tillage of sloping fields gives the possibility of smooth beardless plowing with simultaneous formation of anti-water erosion ridges and intermittent furrows with barriers on the arable surface.

The linear-stepped plough for main tillage of hillside fields is equipped with bodies for turnover of layers within own furrow and with cutting discs forming ridges and interrupted furrows with barriers on arable surface.

To provide the required quality of work diameter of the cutting spherical disk should be within 420-510 cm, and the angle of its installation 28-32º, minimum angle the sector of cutting of the linear-stepped plough should be 49º and the depth of the sector not less than 10 cm, the cutting spherical even body not less than 110 cm.

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