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Justification of technological parameters of disk tillage working bodies

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Justification of technological parameters of disk tillage working bodies

K Shavazov[1*], P Tonapetyan[2] and M Karapetyan[3]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Uzbekistan, Tashkent
[2] National Agrarian University of Armenia, Erevan, Armenia
[3]Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, Moscow, Russia

E-mail: kadirjon.shavazov@bk.ru, Karapetyan.martik@yandex.ru

Abstract. The article discusses the state and current issues of the development and production of disk tillage working bodies. Special attention is paid to the problems of choosing technological parameters, improving technological efficiency and justifying the technological parameters of disk tillage working bodies. It is noted that the proposed tillage technology was tested in the non-irrigated rain-fed and foothill zones of Uzbekistan and the Caucasus region, for spring and winter grain crops, which gave an excellent result.

1. Introduction

Modern disk tools - harrows, huskers, cultivators are designed mainly for surface cultivation of lowland areas. The use of these tools for agricultural purposes especially increased when new technologies of land cultivation, including minimal, began to be widely introduced [1-4].

Minimal tillage technology has been tested in non-irrigated mountainous and foothill zones of Uzbekistan and the Caucasus region, for spring and winter grain crops. Of the tools of surface tillage – paw cultivators and disc huskers, harrows - a relatively good result was given by a disc harrow [5-7].

As a result of experimental studies, the design and operational disadvantages of these harrows have been established, which arise mainly when processing slopes, starting with a slope of 5^0.

Of the identified shortcomings, it should be noted:

- deviation of the axis of symmetry of the harrow from the longitudinal axis of the unit;
- unevenness of the depth of the stroke of the discs along the width of the grip. When working, the upper disks on the slope are buried superficially, and at a given depth of 7 cm, the upper organs come out of the soil, as a result of which the treatment is repeated several times;
- at small values of the angle of attack - $10\text{-}20^0$, the disks with a convex part repel the soil. As a result, the vertical component of the resistance increases, pushing the discs out of the soil, the depth of the upper discs decreases, going beyond the tolerance field.

These and other disadvantages dictate a more in-depth study of surface tillage tools aimed at improving the technical and operational performance of disc harrows.

In this paper, the issues of optimizing the parameters of disk harrows intended for operation in the mountainous zone of agriculture are considered.

The performance of disk guns is regulated by two parameters: the angle of attack θ and the load Q on the frame. When working in heavy, compacted soils, the values θ and Q increase, which leads to ensuring the consistency of the depth of processing, improving the degree of weed pruning and loosening of the soil.

2. Materials and methods

Let us consider the impact of the angle of attack of the disk on the technological process of tillage [7].

Figure 1 shows two disk positions at the minimum value of the angle of attack θ_A and at a value less than acceptable θ.

According to Fig.1, at the value of the angle of attack, at its lowest value, the disk with its convex surface AS protrudes the soil, increasing the component of resistance R_z that removes it from the soil. The angle of attack in this case will be equal to:

$$\sin\theta_A = \frac{AB}{r'}, \quad (1)$$

Where, r'- is the radius of the section corresponding to the depth of the disk stroke. In the diametrical section, it corresponds to the radius of the ball, and AB corresponds to the radius of the disk.

Let's determine the permissible minimum value of the angle of attack, at which the resistance of pushing the disk out of the soil will be minimal.

The parameters of existing disc harrows are as follows: disc diameter - $2r$=450; 510; 610; 660 mm, curve radius R=520-600 mm, angle of attack θ =10-22^0.

The above parameters are accepted according to GOST 198-59.

The angle of capture of the disk -2ε, which is equal to half of the central angle of the arc of the diametrical section, is assumed to be 22-26^0.

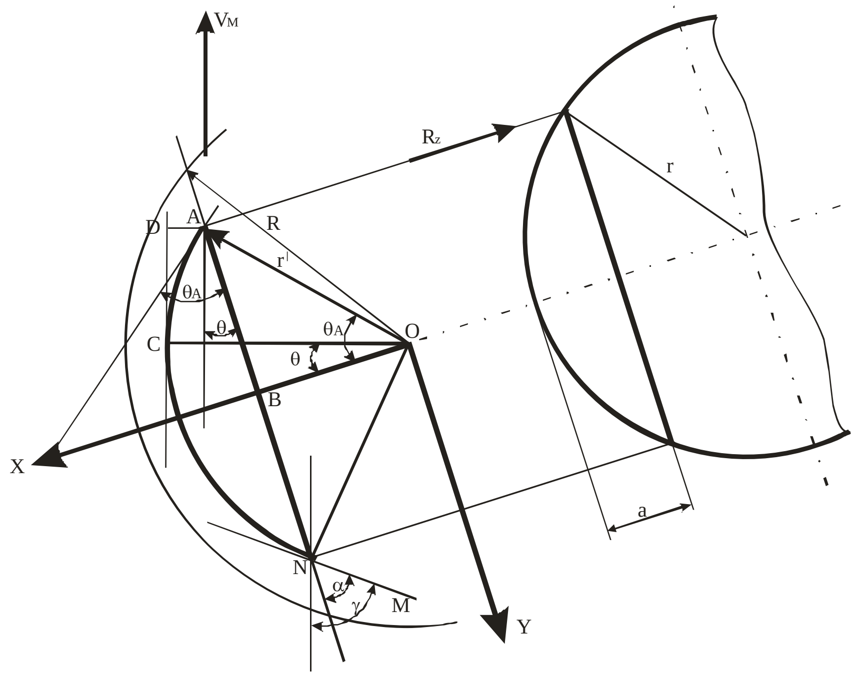

Figure 1. Scheme of justification of the angle of attack parameter of the disk harrow.

We should note that discs with a diameter of 450 mm, are mainly produced, the radius of the curve of the surface is 520-600 mm, the angle of attack is θ equel 10-22^0, which is regulated by the values 12,15,18 and 21^0 to ε =22-26^0.

3. Results and discussion

Let's determine the length of the *AB* catheter (figure 1):

$$AB = \sqrt{r^2 - (r-a)^2} = \sqrt{2ar - a^2}, \quad r' = \sqrt{R^2 - (r-a)^2},$$

where R - the radius of the disk curve.

We have r =22,5 sm, R=52 sm. Taking a=10 sm, we get AB=187 mm and $sin\,\theta_A = \frac{187}{520} = 0{,}36$, $\theta_A = 21^0$ i.e. at point A, the angle of attack is $\theta_A = 21^0$ obtained less than which is not allowed, while at value the process of soil bulging is inevitable $\theta_A = 10^0$.

Note that if in horizontal terrain the forces acting on the harrow sections from the right and left sides balance each other, then on the slope, in fact, due to the difference of these forces, the unit deviates from the specified direction of movement.

Let's determine the amount of soil compaction *AD* (the vertical length drawn from point A to the tangent *AC*), for which we write the coordinates of point *C*:

$$\left.\begin{aligned} x_c &= r'\cos\theta\,, \\ y_c &= r'\sin\theta\,. \end{aligned}\right\} \tag{2}$$

Since the angular coefficient of the tangent drawn at point C is equal to $K_C = -tg\theta$, the equation of a straight line passing through this point will be:

$$y - r'\sin\theta = -ctg\theta(x - r'\cos\theta). \tag{3}$$

The length of the vertical perpendicular AD is defined as the distance of point A from the straight-line *CD*, for which equation (3) is represented as follows:

$$x \cdot cot\,g\,\theta + y - \frac{r'}{sin\,\theta} = 0.$$

Based on the values of the coordinates of point A, $x_A = r'\cos\theta_A\,, y_A = r'\sin\theta_A$, the length of the line *AD* = *d* will be:

$$AD = d = \left|\frac{ctg\theta \cdot r'\cos\theta_A + r'\cdot \sin\theta_A - \frac{r'}{sin\,\theta}}{\sqrt{ctg^2\theta + 1}}\right|, \text{ or}$$

$$AD = d = \left|r'[cos(\theta_A - \theta) - 1]\right|. \tag{4}$$

Given the parameters of the disks of the BDN-3.0 harrow, we get:

$$d = 50{,}48[cos(22 - \theta) - 1].$$

In the last expression, giving the angle of attack θ a value of 0-22^0 we get the value d corresponding to the convex part of the surface of the disk AC, crushing the soil.

The regularity of the curve change $d = \phi(\theta)$, is shown in Fig.2. Analysis of the data of this graph shows that less than 10^0 angle of attack cannot be taken.

Increasing the angle of attack improves the smooth operation of the disk, while the mass of soil on the arc AB can accumulate, which will lead to the cessation of soil sliding on the surface of the disk. From this point of view, the worst conditions will appear around the point N, from the fact that the soil slip condition $\gamma < 90 - \phi$ is violated (Fig. 1). Let's determine the dependence of the angle γ change on the magnitude of the angle of attack θ and set the permissible maximum value of the permissible θ_{max}, after which the rotation of the disk stops. At the inflection point N, the angle formed by the tangent NM with the X axis will be according to figure 1 $tg\alpha = \frac{BN}{BO}$, $BN = \sqrt{2ar - a^2}$, $BO = \sqrt{r'^2 - 2ar + a^2}$, then:

$$tg\alpha = \frac{\sqrt{2ar - a^2}}{\sqrt{r'^2 - 2ar + a^2}}. \tag{5}$$

According to Fig. 1 $\alpha = \gamma - \theta$ and in addition, taking into account the expression $\gamma < 90 - \phi$ condition of soil sliding on the surface of the disk, we get:

$$\theta < 90^0 - arctg\left(\frac{\sqrt{2ar-a^2}}{\sqrt{r'^2-2ar+a^2}}\right) - \phi. \quad (6)$$

We have: $r' = 505mm, r = 225mm,$ the angle of friction of the soil on the surface of the disk $\phi = 25$, then we will rewrite the expression (6) as,

$$\theta < 90^0 - arctg\left(\frac{\sqrt{450 \cdot a - a^2}}{\sqrt{505^2 - 450a + a^2}}\right) - 25^0. \quad (7)$$

The last expression reflects the dependence of the optimal value of the angle of attack of the disk (harrow battery) on the depth of tillage $\theta = \varphi(\alpha)$, the graphical view of which is shown in Fig.3.

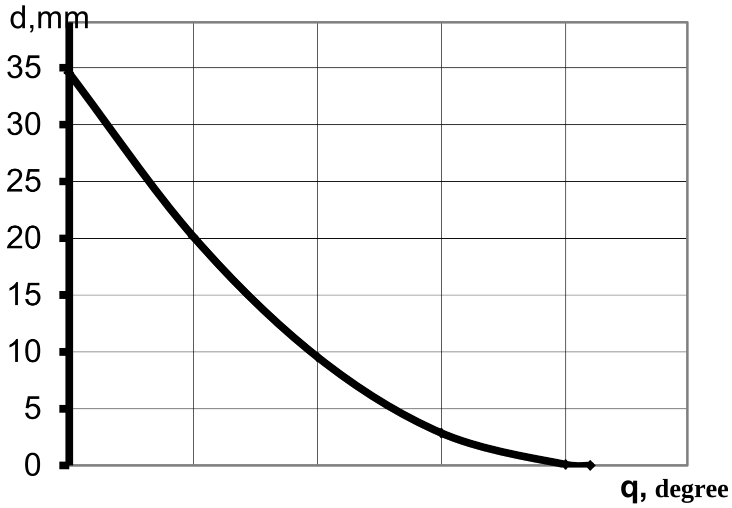

Figure 2. Dependence of d on the angle of attack θ.

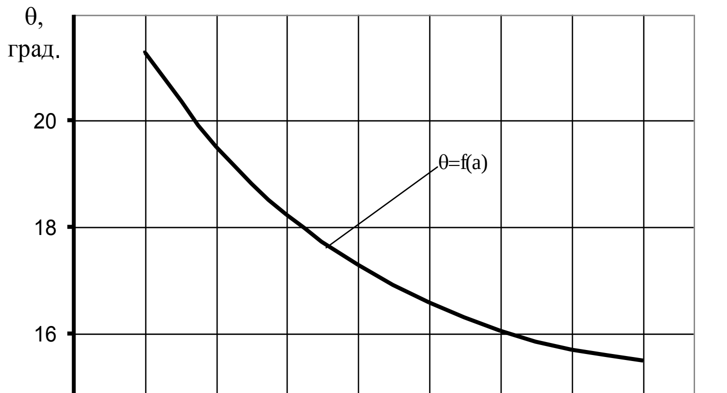

Figure 3. Changing the angle of attack from the depth of the stroke.

4. Conclusions

The calculated data obtained, presented in Figure 3, allow us to choose with sufficient accuracy the optimal value of the angle of attack, which ensures the specified technological quality of surface tillage, i.e., the depth of tillage.

The proposed tillage technology has been tested in non-irrigated rain-fed and foothill zones of Uzbekistan and the Caucasus region, for spring and winter grain crops, which gave an excellent result.

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