AJEMA GLOBAL RESEARCH NETWORK

AMERICAN Journal of Engineering, Mechanics and Architecture
Volume 01, Issue 10, 2023 ISSN (E): 2993-2637

The Use of Disc Chisels in Surface Treatment Between Garden Rows

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Abstract: In the article, the improvement of the level of soil compaction and the loss of plant residues was determined in the experimental tests, when using toothed chisels for surface treatment after the main cultivation between the garden and vineyard rows, compared to traditional cultivators. A theoretical analysis of the geometric dimensions of disk chisels for surface treatment with minimal energy consumption and fulfilling agrotechnical requirements was presented. Different types of disks were analyzed in the analysis.

Keywords: basic soil cultivation, disk, combination, parametersi, problem, stability, elements.

INTRODUCTION

The working bodies of disc harrows and ploughers, depending on their purpose, working conditions, design and surface shape, are divided into separate groups.

According to their purpose, disc tillage implements can be used for field, garden and swamp purposes. Field disc harrows are designed for basic soil cultivation after harvesting the predecessor and for cutting the soil after plowing. In crop rotations with a gap in time from harvesting the predecessor to the subsequent crop, lighter tillage tools are used - disk hoeing machines for cultivating the soil to a shallow depth (4...6) cm in order to preserve moisture from evaporation and obtain provocative weed shoots. The working bodies of such tools are characterized by a smaller diameter, less load on each disk, and a smaller radius of curvature of the spherical surface disc, as well as a smaller distance between discs in one row compared to disc harrows, which can be explained by the smaller volume of soil processed by cultivators.

LITERATURE ANALYSIS AND METHODS

The most common disk tillage implements - disk harrows - are equipped with smooth spherical disks with a solid or cut blade, conical disks and spherical disks with a corrugated surface to the depth of immersion in the soil. Smooth spherical discs with a solid blade of increased diameter (450...600 mm) are used when cultivating the soil to a depth of up to 14 cm and the presence of large-stemmed crop residues on its surface. And vice versa, disks of smaller diameter - when the soil is peeled to a depth of 4...6 cm and there are light crop residues on the soil surface, such as chopped straw. Discs with a solid blade cut crop residues most completely, but such discs under certain conditions (increased humidity and depth of soil cultivation) clog more easily due to the appearance of the phenomenon of dragging with loss of speed. Cutting discs, even with relatively small diameters, more reliably capture crop residues and cut them or step over them, penetrate deeper into the soil more easily and are more constantly engaged with the dense bottom of the furrow, which helps maintain disc rotation, and therefore eliminates the phenomenon of dragging and clogging of harrows soil and crop residues. The shape and size of the disc cutouts vary depending on the working conditions. Discs with cutouts along the periphery are called “daisy”. The first disks of the “daisy” type were installed on battery-type harrows BDT-7, BDT-3, etc. and had trapezoidal cutouts (Fig. 1). Subsequently, discs with semicircular cutouts appeared different sizes (Fig. 2). Discs with larger cutouts with a recess into the disc of up to 30...60 mm (Fig. 2 a) are designed to simultaneously cut crop residues and provide more reliable adhesion to the soil. Discs with cutouts with a radius of up to 30 mm (Fig. 2 b) are mainly designed to ensure more reliable rotation of the disc.

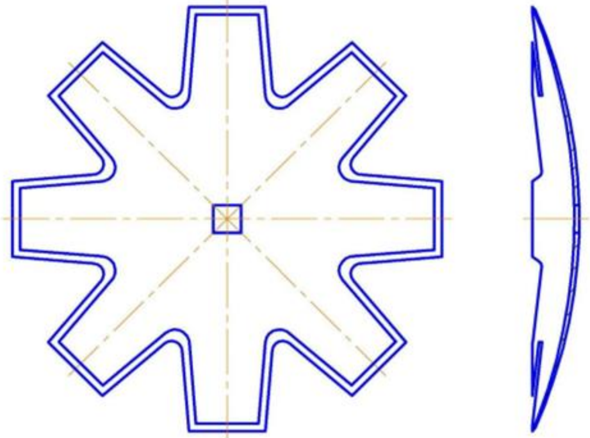
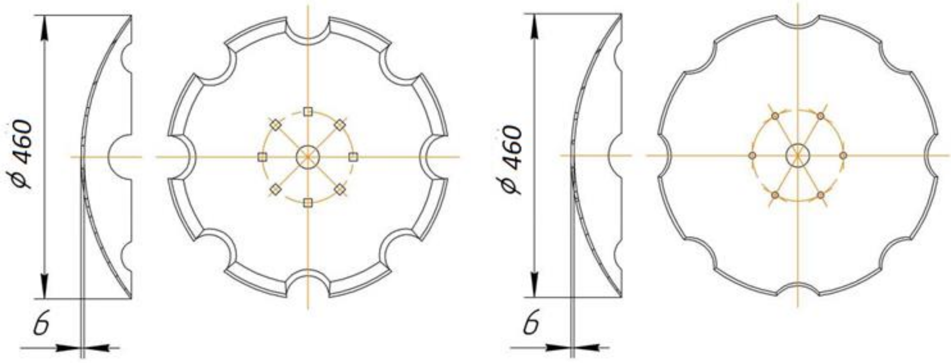
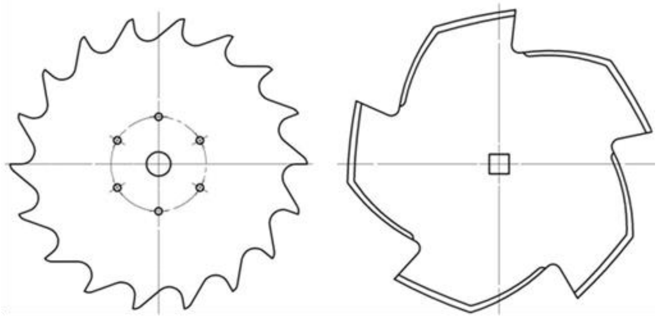


Figure 1. Chamomile harrow disc with a trapezoidal cutout

In order to ensure more reliable rotation of the disk in accordance with the forward speed of the unit and cutting large-stemmed crop residues (corn, sunflower, etc.) the discs must have asymmetrical cuts that ensure sliding cutting (Fig. 3)[1]. These disks have cutouts oriented towards the center of the disk, and one side of the cutout to its top is made radially in a straight line, the other part of the cutout, mating with the radius of the disk, forms a line that ensures sliding cutting of crop residues falling into the cutout. Thus, the presence of structural elements in the form of disc cutouts allows you to capture and fix the stem in the soil and ensure cutting of crop residues.



a – disks with cutouts 30...60 mm; b - disk with cutouts up to 30 mm
Figure 2. Disks with round cutouts along the periphery of the disk



a) **b)**

Figure 3. Discs for cultivating soil and chopping large-stemmed row crops and shrubs

Large diameter discs with similar cutouts “FLEO-FLEO” from Quivogne (800...850 mm) (Fig. 3b) are used for cultivating soil to a depth of 20 cm and crushing coarse crop residues and shrubs. Conical disks are of interest (Fig. 4). Conical disks always maintain their working angle (the angle of inclination to the horizontal of the tangent to the surface of the disk) when worn. Such discs are easily buried in the soil, but do not crumble the soil well as the depth of its cultivation increases.

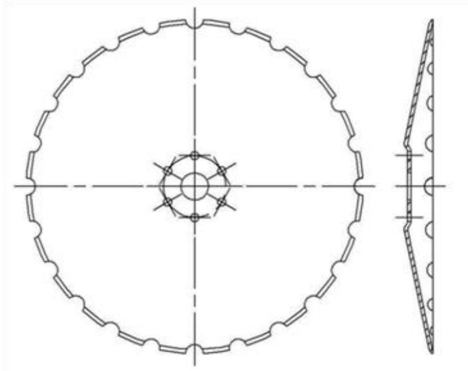


Figure 4. Conical disks

Therefore, conical disks in combination with other working bodies with increased crumbling properties show good results. Discs with a diameter of 430 mm are widely used on disc Carrier harrows and combined units from Vaderstad (Sweden), as well as on Qualidisk harrows from the Kverneland Group with a diameter of 573 mm.In order to more intensively chop crop residues.To crumble the soil and mix it, some foreign companies use spherical discs with a grooved blade on disc harrows (Fig. 5). Discs of this type are produced by Krause and Kuhn and are called A-discs (by Bednar Strom).

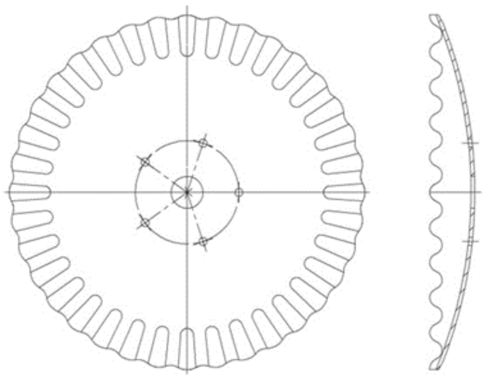


Figure 5. Spherical discs with grooved blade

There is also a known domestic development (Fig. 6) of a spherical disk working body, the peripheral part of the surface of which is made wavy to ensure smoothly repeating changes in the angle of attack from its initial value [2]. The wave of the disk, starting from the cutting edge, is made decreasing towards the center of the disk with a transition to a sphere. Treatment with such a working body should ensure an increase in the quality of soil cultivation while reducing energy intensity. A common disadvantage of all spherical discs is the formation of occipital pressure on the blade during external sharpening and a convex outer sphere, especially at low and medium angles of attack, which is one of the reasons for the violation of directional stability of the disc harrow. In order to eliminate this drawback, disk working bodies are proposed with a more complex external and internal surface. As the curvature of the disk increases, i.e., the radius of the sphere decreases, the soil crumbles better and mixes more intensively with crushed crop residues. However, in this case, the penetration deteriorates and technological reliability decreases.

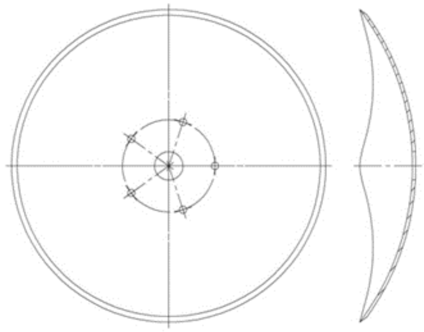
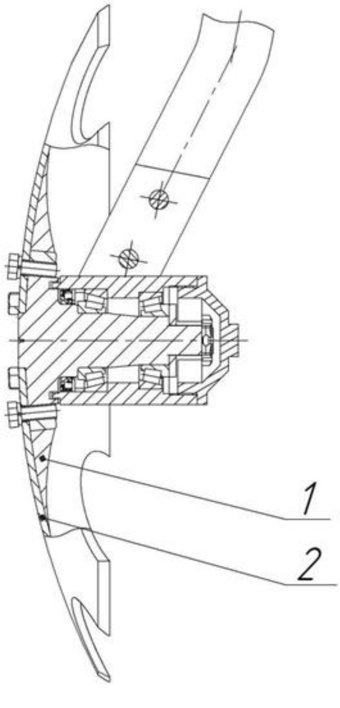


Figure 6. Spherical disk with varying angle of attack

An increase in the internal radius of the sphere, although it increases depth, reduces soil crumbling. The desire to combine all the necessary parameters in one disk - good depth, increased degree of soil crumbling and disk stability - led to the need to develop a new disk with a varying radius of the sphere from the blade of the disk to its center (Fig. 7) [4]. In such a disk, the peripheral part of the disk sphere in the area of maximum penetration of the disk into the soil is made along a large radius, and then towards the center it decreases according to the Archimedes spiral or another law with a smooth decrease in the radius. In the central part of the disk there is a platform for attaching the disk to the bearing unit housing. Ring 1, in conjunction with the inner surface of the sphere of disk 2, provides a new surface, which is an annular curved groove around the bearing assembly when installed on the inner sphere of the disk.



1 – ring; 2 – disk

Figure 7. Spherical disk with floating radius of curvature

This annular trench, depending on the height of the ring and the shape of its section, provides a new trajectory of formation turnover with a decreasing radius of curvature and increased soil crumbling. Ring 1 is replaceable and can be selected depending on the type of soil and its condition. Obtaining the shape of the inner surface of the disk can have different designs. The main technological parameters of the working parts of disc harrows and cultivators, ensuring the quality of soil cultivation in accordance with the initial requirements, high technological reliability and efficiency include disc diameter D and the radius of curvature of the disk sphere R. Many technological indicators of the operation of disc harrows and cultivators depend on the value of these parameters: the quality of soil crumbling, penetration, crushing and incorporation of crop residues, technological reliability, and disc working width. The procedure for calculating the parameters of the disks depends on the physical and mechanical properties of the soil, predecessors, the method of harvesting them, which determine the working conditions, the technology for preparing the soil for the subsequent crop, which determines the initial agrotechnical requirements, as well as on the technological scheme of harrows and cultivators. Depending on the operating conditions and initial requirements, the priority requirements for the quality and operational performance of the implement are determined. Taking these requirements into account, a range of disk parameter values is selected, which are adjusted when considering other indicators. In the scientific literature there are a large number of analytical dependences of the values of disk parameters and their orientation in the soil on indicators characterizing operating conditions, accompanied by experimentally confirmed data. But, unfortunately, in most cases these results are far from reproduced in practice due to constantly changing working conditions. This circumstance indicates the need to conduct experimental studies under a variety of conditions, even critical ones. In such complex objects as soil and research related to it, preference should be given to experimental work. Theoretical research should serve as an initial guideline for the selection of factors acting on the object and the direction of movement towards the optimum. When cultivating winter cereal crops after late-harvested row-crop predecessors using modern technology, the main tillage is carried out with disc harrows. At the same time, working conditions are often characterized by increased soil hardness and the presence of a large amount of large-stemmed crop residues. After harvesting cereal crops, the soil is usually easily cultivated and stubble crops do not require additional crushing - the operating conditions for disc harrows and hullers are easier. In this case, the ranking of soil tillage quality indicators changes. A completely different approach will be required for overdried or waterlogged soil. In order not to miss the recommended sowing time, as a very significant factor for the future harvest, sometimes it is necessary to cultivate the soil even in such harsh conditions. However, in any condition of the field to be processed, one should first consider the issue of technological reliability, which depends on the clogging of the inter-disk space with soil and crop residues, when it is impossible to continue working. Due to design features, this parameter is the most important for battery-type disc harrows. These harrows have an interdisc distance of only 220 mm on one battery and all discs rotate synchronously. These two circumstances are the reason for the frequent clogging these harrows. Therefore, for battery-type harrows, one should begin solving the problem of optimizing disk parameters with the complete elimination of clogging of the harrow with soil and crop residues. For this reason, many manufacturers have stopped producing battery-type harrows, although they have not yet exhausted their capabilities and have a number of advantages over harrows with front-mounted discs on a frame in several rows on individual stands. With this arrangement of working bodies, the interdisk distance increases by 1.5...2 times compared to battery-type harrows. And under these conditions, the problem of clogging the interdisk space with soil and crop residues disappears. Soil crumbling by disc harrows and ploughers depends not only on soil conditions, but also on the parameters of the discs, their orientation in the soil and the parameters of placement on the frame. The soil, after being torn away from the monolith, rising along the inner surface of the disk sphere, crumbles due to compression and bending deformations. The smaller the radius of the sphere, i.e. The greater its curvature, the higher the soil deformation, and therefore crumbling. The degree of soil crumbling also depends on the angle of attack of the disks. Increasing the angle of attack of the discs improves the quality of tillage. But excessive attention to this parameter can lead to clogging of the harrow with soil and crop residues. This is explained by the fact that with an increase in the angle of attack, depending on the operating conditions, the disks are pulled through without rotation, and the permeability of the soil mass in the narrowing space between the disks decreases. Increasing the tillage speed and increasing the curvature of the discs contributes to better mixing of crop residues with the soil. But these two factors reduce depth at the same diameter and increase soil resistance. Earlier in traditional technologies of harvesting and moldboard tillage no attention was paid to grinding crop residues. All the straw was pulled from the field and stacked. With minimal and soil-saving technologies for soil preparation, when harvesting almost all main crops, all the straw is crushed simultaneously with harvesting and the only question left is to embed it in the soil when processing with disc harrows or leave it to protect the soil from erosion and soil deflation when its surface treatment with flat cutters. Therefore, the problem of crushing crop residues with disc implements has almost today migrated to the field of harvesting agricultural crops.

Summarizing the above, it should be noted that the selection of disc parameters for harrows and cultivators requires an integrated approach.

Despite the bundance of different types of disk working bodies, spherical disks remain the most common. The classical calculation of the parameters of such disks [5,6,7] is not without drawbacks, but to this day remains the most suitable of the proposed theories for predicting the geometric parameters of the disk at the first stage of design. All geometric parameters of spherical disks are interdependent and jointly determine its quality and energy indicators. Due to the heterogeneity of the treated environment - soil, the recommended values of all disk parameters are mainly of an interval nature. The sequence of determining disk parameters for different layouts differs from each other. If we accept that the weak link for single-row or double-row disc harrows and battery-type cultivators with synchronous rotation of discs is the clogging of the inter-disc space, then you should first select the parameters on which this indicator depends. It is known that the clogging of disk harrows and ploughers depends on the physical and mechanical properties of the soil, its moisture, the presence of crop residues, the diameter of the disk, the radius of its sphere, the interdisk distance in the battery, the depth of soil cultivation, and the angle of attack of the disks.

As already noted, each combination of operating conditions has its own optimal disk parameters. However, most of the parameters cannot be adjusted depending on the current conditions. These include parameters such as the diameter of the disk, its spherical radius and sharpening angles. The angle of attack of the disk and the depth of tillage should be considered adjustable parameters. Taking into account the presented structure of factors that determine the clogging of harrows and ploughs, preliminary studies should be carried out under the most complex combination of working conditions. The basic level of disk diameter can be adopted based on preliminary calculations.

For battery-type disc harrows, the diameter of the disc is first determined from the ratio [5]:

$D=ka$ (1)

where a is the depth of tillage mm;

k – coefficient determined by operating conditions.

The coefficient k for disc harrows is recommended within 4...6, for hullers - 5...6. The more dangerous the possibility of soil clogging the inter-disk space (increased soil moisture, depth of tillage, amount of crop residues on the soil surface, increased angle of attack, soils with increased stickiness), the higher the coefficient k is chosen. The clogging of harrows and ploughs, in addition to the diameter of the disc, affects also the inter-disk distance in batteries, which is determined depending only on the depth of tillage, which is determined by the expression:

$$b \geq 1,5a \qquad (2)$$

where b is the interdisk distance, mm;

The interdisk distance for battery-type harrows is determined from the expression

$$b = 2\sqrt{h_n (D - h_n) tg\alpha}, \qquad (3)$$

where hn is the permissible depth of the ridges at the bottom of the furrow according to the initial requirements. For disc harrows and ploughers, the diameter of the disc D and its radius of curvature of the internal sphere R are related by the relation [5,7]:

$$R = \frac{D}{2\sin\varphi}, \qquad (4)$$

where φ is half the angle at the vertex of the OAB sector (Fig. 8). In a section of a disk (Fig. 8) in a vertical position with a plane passing through the axis of rotation, with a known value of the disk diameter D, the radius of curvature can be calculated using expression (4) with that the clearance angle is negative.

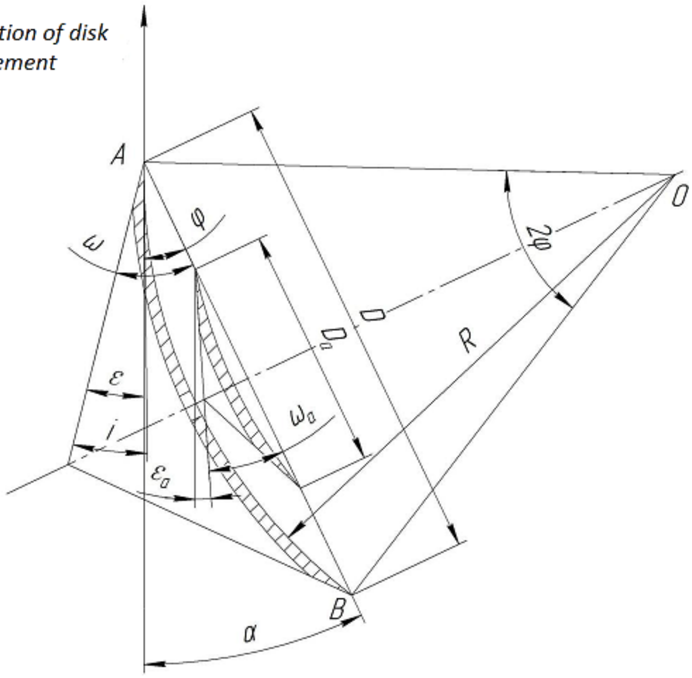


Figure 8. Elements of the geometry of a spherical disk

$$\varphi = \omega - \varepsilon - i,$$

For a positive clearance angle ε where i is the sharpening angle (the angle between the perpendicular to the radius of the sphere at points A or B and the projection of the blade plane, it is recommended to take within 12°...25°).

However, this section is not working. Therefore, let us consider the cross-section of the disk at soil level when buried to the maximum planned depth a. For this section, the angle of attack α is equal to:

$$\alpha = \omega_a + \varepsilon_a \qquad (5)$$

In this expression, the angle ε_α must be greater than 0° to eliminate the phenomenon of occipital pressure. Therefore, the angle ε_α is recommended accept within 3°... 5°. Using the accepted values of α and εα, we find the angle of the cone generatrix in the section at a height a from the bottom of the furrow ω_α.

$$\omega_\alpha = \alpha - \varepsilon_a \qquad (6)$$

And then, given that [8]

$$tg\omega_{\alpha} = \frac{D_a}{Dtg\omega}, \tag{7}$$

where D_a is the cross-sectional diameter of the disk at the level of its depth a, mm;

$$D_a = 2D\sqrt{\frac{a}{D}(1-\frac{a}{D})},$$

Next, having determined ω from expression (7), we determine the angle φ at the top of the sector using expression (4), i.e.

$$R = \frac{D}{2\sin(\omega-\varphi)}, \tag{8}$$

For new generation disc harrows with individual fastening of each working element to the frame and their frontal arrangement in several rows, in contrast to disc implements with a battery arrangement of discs, soil jamming between the discs is practically not observed. This is explained by the fact that in these implements, due to the placement of working bodies in 3 and 4 rows, the possibility of clogging the inter-disc space is unlikely, since the distance between the discs in the rows is 1.5...2 times greater than in battery-type harrows. And for disk ploughers, the issue of soil jamming between the disks does not pose a danger due to the small depth of tillage, but consequently, a small volume of processed soil. Consequently, for harrows and cultivators with individual disk fastening to the frame, it is necessary to choose the disk diameter based on other principles. In this case, the main indicator is the ability of the disc to cut crop residues. In any case, the diameter of the disk should be chosen as minimal as possible, since the depth depends on it. When operating a spherical non-cutting disc, there may be cases where crop residue, such as corn cob, is pushed out of the angle formed by the field surface and the disc blade. To eliminate this phenomenon, it is necessary to increase the diameter of the disk [5]. In order to solve the alternative situation that arises in choosing the diameter of the disk, it is necessary to again conduct experiments on choosing the optimal diameter of the disk, taking into account the interests of deepening and cutting crop residues without unloading them in front of the harrow, taking into account the conditions of soil cultivation. However, to establish the scope of the experiments, one should first be guided by the recommendations on the diameter of the disks, previously developed under the conditions of previous technologies. At the same time, in the same experiment it is necessary to determine the distance between the rows of disks. In this case, it is necessary to test disks of different designs for each soil condition: disks with a smooth blade without cutouts, with cutouts of various configurations, including with a constant cutting angle, etc. Selection of other parameters of disks for harrows and cultivators with individual fastening of working tools and battery tools almost the same type. And finally, choosing the type and parameters of disks, as well as their placement must be accompanied by testing in the most extreme soil conditions. Such conditions are indeed rare, but we should not forget that even in these rare cases it is necessary prepare the soil and sow the next crop in the crop rotation in a timely manner. The angle of attack of the disk α, its angle of inclination to the vertical β and the soil tillage speed V are of independent importance in increasing many of the qualitative and technical and economic indicators of disc harrows and cultivators. When using disc implements, previously all recommendations noted a speed of 6...7 km/h as the most optimal. However, at that time disc implements were used mainly only for cutting up plowed soil. In modern technologies they are used for basic tillage. The results of the studies show that with an increase in the translational speed of spherical disks, the traction resistance also increases significantly [7]. So, with□□□□ 15□ increase in speed from 5.8 to 10.8 km/h, i.e. by 1.86 times, causes an increase in the traction resistance of the disks from 40 to 80%, and at □□□□ 30□ by 25...65%. This means that the increase in traction resistance lags behind the increase in speed. And even based on this indicator alone, it makes sense to increase the speed of tillage at higher speeds. Professor G.N. Sineokov and I.M. Panov note that “with an increase in the speed of the tractor, the range of soil thrown by discs increases sharply, therefore the speed of movement of disc plows and ploughs should not exceed 7 km/h” [5]. But this problem has already been solved on modern disc guns. They are equipped with reflectors of soil lumps that come off the disks when working at high speeds, which not only prevent the soil from being thrown chaotically in different directions, but also, when they hit the reflector, they additionally crumble. It was also noticed that when processing at higher speeds, the degree of soil crumbling increases, technological downtime due to gun clogging is reduced. The choice of angle of attack is a critical step in developing initial data for the design of harrows and ploughs. The range of angle of attack adjustment is wide. So, for disk ploughers, it is 30...40°, for disk harrows - no more than 25°. On foreign-made disc harrows and some domestic models, the angle of attack is not adjustable and is 18...20°. Not only the degree of soil crumbling, but also the width of the disk and the degree of mixing of soil and crop residues depend on the angle of attack. All these indicators increase as the angle of attack increases. But depending on the geometric parameters of the disks, as the angle of attack increases, the angular velocity of the disk decreases, dragging begins and, as a result, the inter-disk space becomes clogged with soil and crop residues. When cultivating the soil with a vertically standing disk, the soil mainly experiences shear deformations, rises to a small height, does not mix well with crop residues, and all this intensifies when cultivating the soil to a greater depth with a plow. The angle of inclination of the discs to the vertical was previously recommended only for disc plows. When the disk is tilted, the lifting of the formation is facilitated and the traction resistance is reduced. However, harrows and mulchers with individual attachment of working bodies with minimal tillage are required to mix the soil with crop residues, which cannot be done without raising the layer to a greater height. And this requirement can only be fulfilled by an inclined disk, onto which the cut layer of soil can be lifted more easily. Thus, when developing the initial requirements for disk working bodies and determining the optimal parameters of the working bodies, one should take into account not only their operating conditions, but also the type of harrow, since the procedure for solving the task at hand depends on the latter.

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