

# Uniformity of the soil tillage depth with tools with disk working bodies

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**Abstract.** The qualitative parameters of tillage with tools with disk working bodies are influenced by a variety of structural, technological and operational factors. One of these parameters is the uniformity of the depth of tillage, and the influencing factors include the relief of the field, the speed of movement, the method of fastening the working bodies and others. The article presents an overview of the ways of attaching individual disk working bodies to the frame and their effect on the uniformity of the working depth. It is proposed to use a combined statistical method for a more reliable and qualitative assessment of the uniformity of the tillage depth.

## Relevance of research

The role of tillage in increasing its fertility is great. Tillage in accordance with the initial requirements is the key to obtaining high yields, affects the development of diseases and pests, crop contamination, soil moisture, its density, resistance to deflation and erosion [6, 9].

In agricultural production, depending on soil and climatic conditions, three main technologies of soil preparation are used: intensive (traditional) technology based on dump plowing, minimal surface technology and direct sowing without pre-tillage (No Till). After harvesting the predecessor crop, surface tillage is carried out with rotary disk tools in order to detain and preserve residual moisture and moisture of the falling residues, sealing weed seeds to obtain provocative shoots and their subsequent destruction by either mechanical treatment or herbicides. When using traditional tillage technology based on dump plowing, disk harrows are used for cutting ploughing, and when using minimal processing technology, basic processing to a depth of 8...12 cm. Even in zero tillage technology, it is often necessary to use disk harrows to level the soil. Thus, when cultivating almost all field crops, disk harrows are used in all applied technologies of soil preparation for sowing [3, 8].

## Problem statement

A number of agrotechnical requirements are imposed on the quality of tillage, the fulfillment of which is possible only taking into account the dependence of quality parameters on

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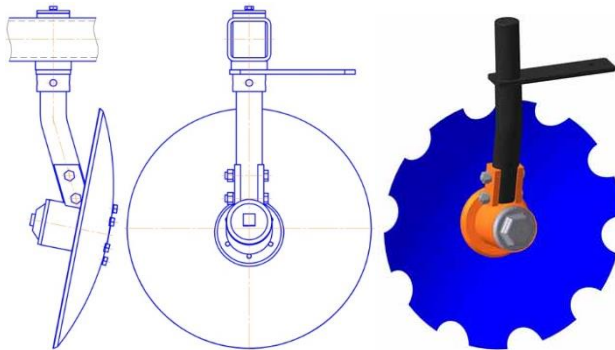
technological parameters when designing tools [4, 5]. With sufficient load on each disk, the whole harrow is buried to a given depth. However, this alone is not enough for tillage within the agrotechnical admission. The uniformity of the depth of tillage depends on many factors: the relief of the field, the method of copying the surface of the field by each working body, the physical and mechanical properties of the soil, the correct setting of the disk harrow or husker [12, 13].

## Presentation of the main research material

It is known that the tolerance for the deviation of the processing depth depends on the magnitude of the depth itself. With an increase in the required processing depth, the tolerance for deviation also increases. So, if the depth of tillage during its peeling is 4... 6 cm, and the tolerance for it is  $\pm 1$  cm, then according to agrotechnical requirements, the tolerance for uneven depth of tillage during its harrowing with disk harrows to a depth of 8 ... 14 cm is  $\pm 3$  cm. Therefore, when choosing the width of the grip for group fastening of working bodies to the frame of individual sections (central or lateral), it is necessary to consider disk harrows and huskers separately [5, 9].

It is also necessary to take it into account when choosing the width of the frame section and the requirements for dimensions during transportation. According to the results of the field profile studies and long-term production practice, it has been established that when the working bodies are rigidly attached to the frame, the permissible width of one frame section of disk harrows is 4 m for the conditions of Krasnodar Territory. For huskers intended for tillage to a depth of only 5...6 cm, it is necessary to apply individual copying of the field surface by each working body with the same width of the frame section. To expand the area of application and improve the quality of tillage, many manufacturers of disk harrows use various designs for individual copying of the soil relief by working bodies, despite the fact that this leads to a potential decrease in the reliability of the tool as a whole and an increase in its cost [11, 14, 15].

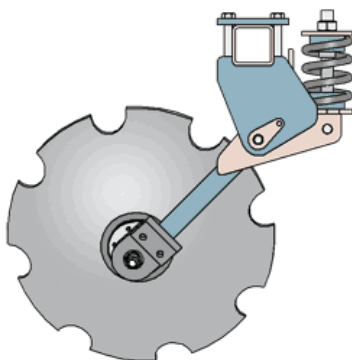
The most common way to connect the working bodies of disk harrows to the frame is a rigid attachment. Such a compound is the cheapest and is used practically on most tools of domestic production (Fig.1).



**Fig.1.** The working body of disk harrows with a rigid attachment to the frame.

Disk harrows with such fastening of working bodies do not differ in any way from battery-type harrows in terms of the uniformity of the depth of their course in the soil.

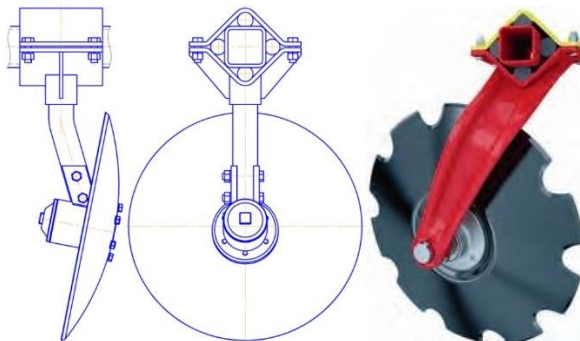
Lemken (Germany) uses disks mounted on prestressed spring suspensions on almost all of its harrows, which provide constant optimal pressure on the disks (Fig. 2).



**Fig.2.** Spring-loaded individual rack of the working bodies of the Ruby 9 disk harrow by Lemken (Germany).

Such a suspension primarily copies the profile of the field, ensuring uniform tillage in depth, protects against breakage when the working body meets with random obstacles in the form of stones, root residues and other objects. In addition, such a suspension also increases the technological reliability of the entire defense as a whole, due to the relative oscillation of neighboring working bodies in the longitudinally vertical plane.

Disk harrows with rubber elastic structural elements from Väderstadt (Sweden) and Amazone (Germany) are widely used (Fig. 3).



**Fig. 3.** Rubber elastic elements connecting the working bodies of disk harrows and huskers with the frame.

When setting the harrow to the required depth, the rubber shock absorbers receive a pre-load, which is used during operation to copy the relief of the field.

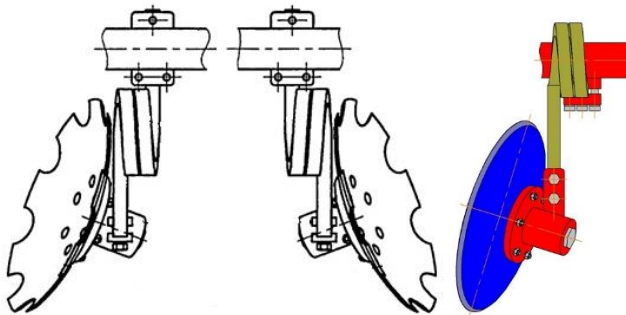
The firm Agrisem (France), Gaspardo (Italy), JSC Belagromashservis (Russia) install disks on spiral-type racks (Fig. 4).



**Fig. 4.** Working bodies of a disk gun on a spiral rack.

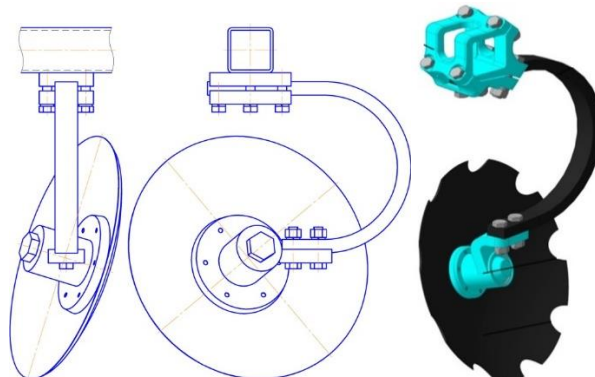
It is noted that the working bodies on the spiral rack, like all other movable suspensions, are well protected from breakdowns when hitting obstacles, reduce resistance due to vibration and increase technological reliability.

At the working body of the disk tool (Fig. 5), the bearing assembly is located on the outside of the disk sphere, and the spiral is oriented so that the spring coils twist and approach each other from the forces acting on the disk [7]. At the same time, the rigidity of the system increases, which contributes to the deepening of the working organ.



**Fig.5.** The working body of the disk tool according to the patent of the Russian Federation 104008.

An arc-shaped rack plays a similar role, which is used on many disk harrows and mulchers from Sunflower (USA), JSC Belagromashservis, Promagro, etc. (fig. 6).



**Fig. 6.** The working body of the disk mulching harrow D-820 "Dominant"

Unfortunately, some manufacturers of disk harrows and mulchers, trying to hide poor quality copying and uneven depth of tillage when demonstrating to potential customers, increase the depth of tillage and almost never open the bottom of the furrow for evaluation.

To achieve higher indexes for the uniformity of the depth of soil treatment, it is necessary to take into account, as already mentioned, the working conditions of tools - the relief of the field, the presence of stones and other solid inclusions in the soil, the condition of the soil.

To assess the relief of the field, it is necessary to profile its surface, according to the results of which it is possible to find the prevailing wavelength, which can serve as a sufficient basis for establishing the width of the frame.

For example, if, based on the results of field profiling, by constructing normalized spectral densities and determining the frequency  $\omega_0$ , at which the spectral density reaches its maximum value and the spectral density value  $\sigma(\omega_0)$  itself at the frequency  $\omega_0$ , it is possible to calculate the prevailing period of irregularities of the studied surface  $L$  by the expression [1, 10]:

$$L = 2\pi \frac{1}{\omega_0}, \tag{1}$$

where  $L$  – the period of irregularities of the investigated surface;

$\omega_0$  – the frequency at which the spectral density reaches its maximum value.

Knowing the value of  $L$  and the variance corresponding to it, it is easy to predict the possible unevenness of the depth of tillage when the working bodies are rigidly attached to the frame.

The uniformity of the depth of tillage with disk harrows and huskers is a very important parameter, but it does not take into account how accurately you can adjust the tool to a given depth.

When assessing the quality of tillage with disk tools, they are usually limited to determining the arithmetic mean  $M_{sr}$ , variance  $D$  and coefficient of variation  $V$  by a series of measurements. This approach does not make it possible to assess comprehensively the compliance of the tillage depth with the depth set in advance and its tolerance.

To more clearly assess, emt of the tillage depth, a combined statistical method for assessing the quality of tillage can be used. If the distribution law of the measured value, i.e. the depth of tillage, is close to normal with the parameters of the arithmetic mean  $M_{sr}$  and the standard deviation  $\sigma$ , then the probability of the depth of tillage within the agrotechnical tolerance is determined by the following expressions [2]:

$$P_1 = P(x_i < M_{sr} - t_1\sigma) = \frac{1}{2}(1 - F(t_1)), \tag{2}$$

$$P_2 = P(x_i < M_{sr} - t_2\sigma) = \frac{1}{2}(1 - F(t_2)), \tag{3}$$

where  $P_1$  and  $P_2$  – accordingly, the probability of tillage in the upper tolerance zone and the probability of tillage in the lower tolerance zone depend on the planned depth;

$t_1$  – the ratio of the difference between the lower agrotechnical tolerance of  $T_N$  and the arithmetic mean of the  $M_{sr}$  measurement series to the standard deviation in the sample of measurements of the actual depth;

$t_2$  – the ratio of the difference between the upper agrotechnical tolerance of the  $T_v$  and the arithmetic mean of the  $M_{sr}$  measurement series to the standard deviation in the sample of measurements of the actual depth;

$F(t_1), F(t_2)$  – Laplace functions.

The probability of the location of the tillage depth within the agrotechnical tolerance is determined by the expression [2]:

$$P(T_N < m_i < T_v) = \frac{1}{2}F(t_1) + \frac{1}{2}F(t_2), \quad (4)$$

Then the area of the field on which the tillage is carried out to the optimal depth is determined as:

$$F_{opt} = P(T_N < m_i < T_v)100\%, \quad (5)$$

. Thus, such an assessment takes into account both the preservation of the average depth of tillage and its standard deviation at a constant average depth.

To obtain a representative sample of the depth of tillage, profiling of the field surface and the bottom of the furrow is carried out using a leveling or measuring rail. However, this is a rather laborious and inefficient process. Therefore, it is recommended to use devices for automatic recording of profiles on an oscillogram with their subsequent statistical processing. To determine the depth of tillage on the oscillogram, it is necessary to determine the offset of the beginning of fixation of the ordinates of the profile of the bottom of the furrow  $Z_{bi}$  and the profile of the surface of the field  $Z_{ni}$ , taking into account the position of the copying wheel and the working body. According to the measurement results, the depth of  $a_i$  tillage and its dispersion are determined from the expression:

$$a_i = Z_{bi} - Z_{ni}, \quad (6)$$

$$D_a = D_n - D_b - 2K_{nb}, \quad (7)$$

where  $D_n$  and  $D_b$  – dispersion of the profile of the field surface and furrow bottom;

$K_{nb}$  – the correlation moment of the connection of the profile of the field surface and the bottom of the furrow.

In this case, the variance of  $D_a$  serves as an estimated indicator of the uniformity of the processing depth.

## Conclusion

Thus, the proposed method for assessing the uniformity of the depth of tillage by the dispersion values allows determining its magnitude, as well as the structure of formation, to assess the quality of disk harrows and huskers fully and to outline ways to improve them.

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