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Optimization of the parameters of the rotary working body for harrowing crops

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Abstract. The rotary harrow loosens the surface layer of the soil when working, removing the soil crust, but the process of how the number of needles in the soil and the diameter of the working body affect it, is not completely understood. These questions are considered in the course of the study. We have supplemented theoretical provisions in relation to passive rotary working bodies.

1 Material and methods of research

The technological process of the multi-functional unit, which combines several operations performed in one pass through the field, implies the presence of an appropriate set of agricultural machines in the design.

The multifunctional unit must be equipped with working bodies for loosening the soil to a given depth and a machine for applying fertilizers.

Rotary working bodies for loosening the soil without a drive (passive) need additional theoretical researches, since they have a relatively small history of their development. In this regard, parameters and operating modes of a rotary working body for crop harrowing are given below [1].

2 Results of study

A rotary working body with evenly spaced needles along the perimeter is a flat disk (rotating in a longitudinally vertical plane). The technological process of interaction with the soil happens when the rotary disk is rolled in the soil layer, the needle is immersed into it, crushing and shifting the soil in the direction of rotation.

The degree of soil loosening, freely rotating in a longitudinally vertical plane of the needle disk on the axis, depends on a certain number of parameters, such as: the number and shape of the needles, the diameter of the disk, the properties of the soil and the translational speed of movement. Based on the above, an analytical study of rotary working bodies is of interest from the point of view of the influence of parameters, the size of the disk and the needles located on it on their interaction with the soil during operation [2].

When the needle disk moves, several needles are immersed in the soil at the same time. In order to determine the total length of the needles, simultaneously submerged in the soil,

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it is necessary to derive an equation for determining the length of the immersed part of one single needle [3]. Knowing the tillage's depth and the disk's size and using the scheme (Fig. 1), we obtain:

$$AB = (r+\delta) - (r+\delta)\cdot\cos\alpha, \qquad (1)$$

$$AB = h - a\cdot\cos\alpha, \qquad (2)$$

where h – depth of processing, m;

a – length of the immersed part of the needle, m;

r – radius of the disk, m;

α – angle, determining the zone, in which the needles are immersed into soil;

δ – length of the needle, m.

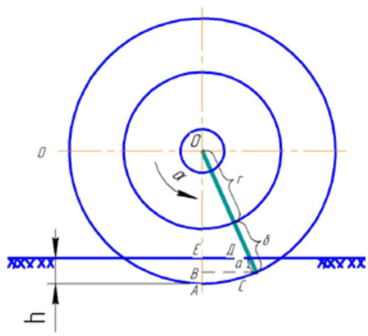

Fig. 1. Diagram to the explanation of the equation for determining the immersed part of the needle

The right parts of these equations are equated (1) and (2):

$$(r+\delta) - (r+\delta)\cdot\cos\alpha = h - a\cdot\cos\alpha, \qquad (3)$$

Then we get the equation in general form:

$$a = \frac{r+\delta-(r+\delta-h)}{\cos\alpha}, \qquad (4)$$

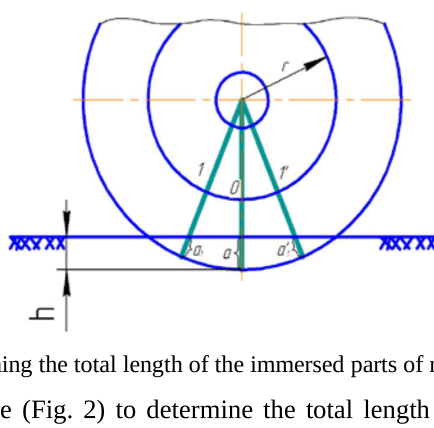

Fig. 2. Scheme for determining the total length of the immersed parts of needles

Let's take the scheme (Fig. 2) to determine the total length of immersed parts of the needles. The sum of immersed parts of the needles is determined by the formula:

$$\sum\frac{a_i}{h} = \sum m_i + \frac{\left(\sum\left(1-\frac{1}{\cos\alpha}\right)\cdot r\right)}{h}, \qquad (5)$$

where m_i – the total number of needles on the disk.

The number of needles immersed simultaneously into the soil per unit area, treated by the needle body, is an important indicator that characterizes the intensity of its impact on the soil [4].

Knowing the number "m" of all the needles on the disk, we find the angle "α" between adjoining needles:

$$\alpha = \frac{360^0}{m}, \tag{6}$$

To determine the zone in which the needles of the flat disk are more or less submerged in the soil, we find the angular gap 2γ.

When dividing the angular interval "2γ" by the angle α, we get the number of needles simultaneously located in the soil:

$$n = \frac{2\gamma}{\alpha}, \tag{7}$$

We find:

$$\gamma = \frac{(\arccos\ R\ -\ h)}{R}, \tag{8}$$

where R – radius of the disk at ends of needles, m,

h – depth of processing (length of the needle), m.

Substituting in equation (7), the ratio (6) and (8), we determine the value "n":

$$n = \frac{2m}{360^0} \cdot \arccos\left(\frac{R - h}{R}\right), \tag{9}$$

or

$$n = \frac{m}{180^0} \cdot \arccos\left(\frac{R - h}{R}\right), \tag{10}$$

The analysis of equation (10) shows that the number of needles, simultaneously located in the soil, decreases, with an increase in the radius of the needle working body and increases – with a decrease in the radius [5].

Therefore, when designing rotary needle tools, it is necessary to take into account these parameters and strive to reduce the size of needle disks, and it is accompanied by a proportional decrease in the mass of working bodies and the tool as a whole, while increasing the density of chips per unit area of the soil, therefore, increasing the degree of its loosening.

We should use the scheme (Fig. 3) to determine the coordinates of the movement of the ends of the needles of the flat disk. The flowing coordinates of the point of the end of the needle (X, Y and Z (axis «OZ» are directed from the drawing to us). We determine the coordinates of the point "B", based on the theory of soil cutters [6] .

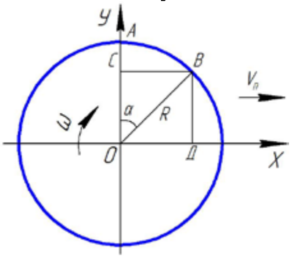

Fig. 3. Scheme for determining the coordinates of the needle end of the flat disk

For the time « t » the center of the disk « O » will move to the distance: $V_n \cdot t$;
where V_n – forward speed.
The disk turned to the angle « α », so:

$$X = V_n \cdot t + R \cdot \sin \omega \cdot t , \quad (11)$$

because $t = \frac{\alpha}{\omega}$; $V_n = r \cdot \omega$; $\lambda = \frac{V_o}{V_n} = \frac{R \cdot \omega}{r \cdot \omega} = \frac{R}{r}$,

where λ – velocity parameter;
r – false radius of the disk's rolling;
ω – angle velocity, so:

$$V_n \cdot t = r \cdot \omega \cdot \left(\frac{\alpha}{\omega} \right) = r \cdot \alpha , \quad (12)$$

Making substitutions in equation (12), we get:

$$X = r \cdot \alpha + R \cdot \sin \omega t = R \cdot \left(\frac{(r \cdot \alpha)}{R + \sin \alpha} \right) = R \cdot \left(\frac{\alpha}{\lambda} + \sin \alpha \right) \quad (13)$$

We have finally:

$$\begin{cases} X = R \cdot \left(\frac{\alpha}{\lambda} + \sin \alpha \right), \\ Y = R \cdot \cos \alpha \end{cases} \quad (14)$$

Note:
1. The right coordinate systems are accepted;
2. The coordinate Z is zero;
3. In the right part of the equation, the part of the sum of the equation (12) will have the following form:

$R \cdot \sin \alpha = X$

3 Conclusions

When optimizing the parameters of the working body of the rotary harrow, we studied the issue of the technological process of interaction of the needle with the soil. It consists in the fact that when the rotary disk is rolled in the soil layer, the needle is immersed into it, crushing and shifting the soil in the direction of rotation. In this case, the degree of soil loosening depends on a certain number of parameters, such as: the number and shape of the needles, the diameter of the disk, the properties of the soil and the forward speed of movement.

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