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Research Article

THEORETICAL STUDY OF THE DISC ROLLER DIMENSIONS OF THE COMBINATION PLUG DEVICE

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ABSTRACT

The article presents the results of the theoretical determination of the main dimensions of the disk reel of the combined plug, which consists of a reel equipped with discs with a smooth working surface and smoothing-densifying working parts equipped with plates forming a fine layer.

According to the results of theoretical studies, it was determined that in order to ensure high-quality crushing of the soil at the depth where the seeds of repeated crops are thrown and compaction at the required level, the depth of immersion of the roller discs into the soil should be 3-5 cm, the diameter should be at least 40 cm, the angle of sharpening should be 60°, and the thickness should be 3 cm.

KEYWORDS

Dimensions, Combination Plug Device, Smooth Working Surface, Smoothing-Densifying Working Parts.

INTRODUCTION

When fields empty of wheat are plowed, the upper layer of soil containing plant residues and weeds is overturned and dumped into the lower layer, as a result of which voids are formed in the plowed area, which, if not eliminated or minimized, will affect the quality of irrigation and row cultivation. In addition, for

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high-quality planting of repeated crops, the condition, density, and evenness of the top layer of the soil should correspond to the agrotechnical requirements for planting. Taking into account the above, the soil clods overturned by the plow body should be compacted, crushed and leveled under the influence of the device. In addition, the device should form a soft layer on the surface of the plow to ensure moisture retention, taking into account the high summer temperature.

Based on the mentioned requirements and the analysis and arrangement of the work of various working parts, the device was developed by the authors, consisting of a roller equipped with disks with a pone-shaped working surface and a smoothing-densifying working parts equipped with plates forming a soft layer (Fig. 1).

The device was developed into a rotary plow widely used in agriculture [1].

METHODOLOGY

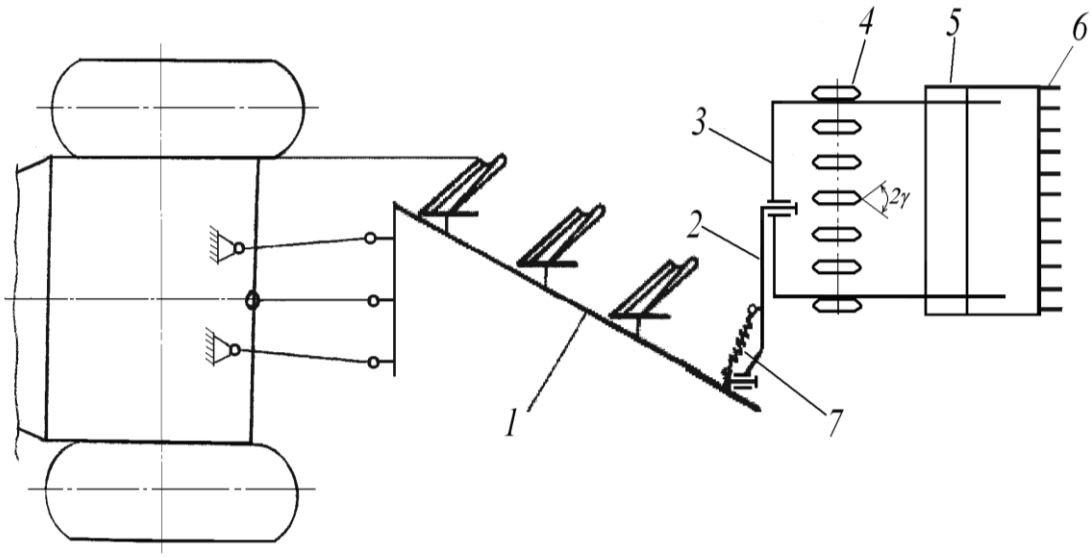

Figure 1. Combined plug device:

1 – plug; 2 – device mounting bracket; 3 – a brush to which the working parts of the device are fixed; 4 – disc reel; 5 – leveler-compressor; 6-plates forming a soft layer; 7 – pressure springs.

We find the diameter of the disk of the plug device from the condition that it passes through the cuts encountered in its path without pushing forward. To do this, we consider the forces acting on the lump interacting with the disk. From the disc side, the lump is acted upon by normal N1 and frictional F1 forces, and from the soil side by normal N2 and frictional F2 forces (Figure 2).

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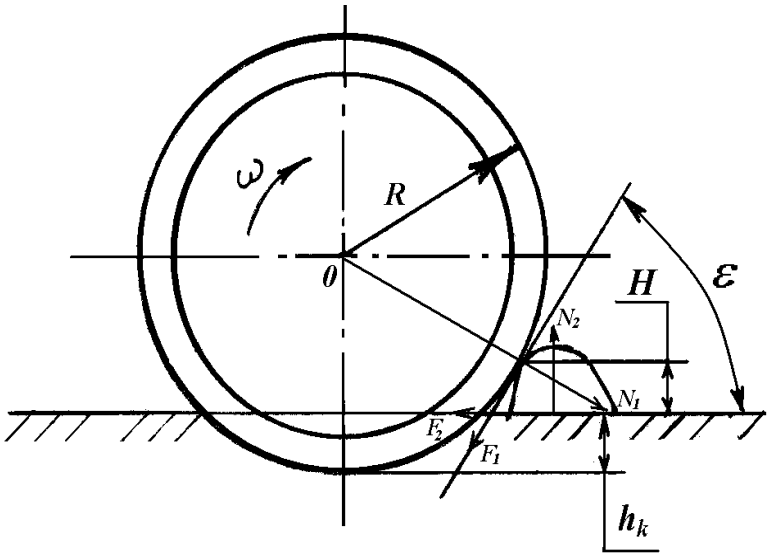

Figure 2. The scheme for determining the diameter of the drive roller disc:

N_1, N_2 - normal forces, F_1,F_2 - frictional forces.

The following condition must be met so that the cut does not move forward [2].

$$F_1 \cos\varepsilon + F_2 \geq N_1 \sin\varepsilon, \qquad (1)$$

where: ε - the angle of deviation relative to the horizon of the attempt made to the point where the disk touches the lump;

$$F_1 = N_1 tg\varphi_1 \text{ ва } F_2 = N_2 tg\varphi_2,$$

where: φ_1 and φ_2 are the external and internal friction angles of the soil.

From the condition of balance of the forces acting on the piece

$$N_2 = N_1 \cos\varepsilon + F_1 \sin\varepsilon = N_1 \cos\varepsilon + N_1 tg\varphi_1 \cdot \sin\varepsilon. \qquad (2)$$

Putting the values of F_1 and F_2 into expression (1), we get the following.

$$N_1 tg\varphi_1 \cos\varepsilon + N_2 tg\varphi_2 \geq N_1 \sin\varepsilon. \qquad (3)$$

Instead of N_2, we put its value according to the expression (3).

$$N_1 tg\varphi_1 \cos\varepsilon + N_1(\cos\varepsilon + tg\varphi_1 \sin\varepsilon) tg\varphi_2 \geq N_1 \sin\varepsilon \qquad (4)$$

We reduce this expression to N_1

$$tg\varphi_1 \cos\varepsilon + tg\varphi_2 \cos\varepsilon + tg\varphi_1 tg\varphi_2 \sin\varepsilon \geq \sin\varepsilon \qquad (5)$$

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From here

$$tg\varphi_1 + tg\varphi_2 \geq tg\varepsilon - tg\varphi_1 tg\varphi_2 tg\varepsilon \quad (6)$$

or

$$\frac{tg\varphi_1 + tg\varphi_2}{1 - tg\varphi_1 tg\varphi_2} \geq tg\varepsilon \quad (7)$$

$$tg(\varphi_1 + \varphi_2) \geq tg\varepsilon \quad (8)$$

or

$$\varepsilon \leq (\varphi_1 + \varphi_2) \quad (9)$$

From the scheme presented in Figure 2:

$$R - R\cos\varepsilon = H + h_k \quad (10)$$

We solve this by considering (9).

$$R \geq \frac{H + h_k}{1 - \cos(\varphi_1 + \varphi_2)} \quad (11)$$

or

$$D \geq \frac{2(H + h_k)}{1 - \cos(\varphi_1 + \varphi_2)} = \frac{H + h_k}{\sin^2(\frac{\varphi_1 + \varphi_2}{2})}. \quad (12)$$

The analysis of this expression shows that the diameter of the coil depends on the size of the lumps on the soil surface, the depth of immersion in the soil, the physical-mechanical properties of the soil, that is, the values of the friction angles φ_1 and φ_2.

The values of N and friction angles φ_1 and φ_2 in expression (12) vary significantly depending on the condition and type of soil. Therefore, in order to ensure the operation of the coil on a large scale, the largest values of *N* and $h_к$, and the smallest values of φ_1 and φ_2 are taken in the calculation.

When *H*=5 см, $h_к$ =5 см, φ_1 = 25° ва φ_2 =35°, it is clear from the expression (12) that the diameter of the coil disk should not be less than 40 cm.

The sharpening angle of the disks is determined by the condition that the soil does not stick to their working surface when the disks sink into the soil and work. In order to determine at which values of the angle γ this

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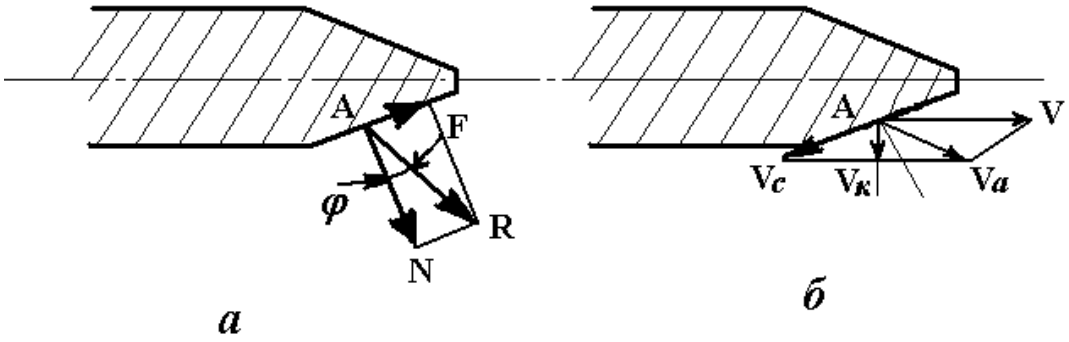
condition is best satisfied, we consider the process of interaction between the disk and the soil particles (Fig. 3).

The soil particles are affected by the normal *N* and frictional forces *F* from the disc-shaped part. They move at a speed V_a in the direction of the force *R*, which is an equal effector of these forces [3].

$$V_a = V\frac{\sin\gamma}{\cos\varphi_1}, \qquad (13)$$

where V-disk is the velocity of the point under consideration



а *б*

Figure 3. The scheme for determining the angle of sharpening the disc

We find the component of velocity V_a perpendicular to the direction of motion.

$$V_k = V_a\cos(\gamma+\varphi_1) = V\frac{\sin\gamma}{\cos\varphi_1}\cos(\gamma+\varphi_1). \qquad (14)$$

It can be stated with full confidence that the probability of the soil sticking to the working surface of the disk is the least at the values of the angle γ that ensure the maximum V_k.

To find the value of γ that ensures V_k is maximal, we explore the expression (14) to the extremum with respect to .

$$\frac{dV_k}{d\gamma} = V\cos\varphi_1\left[\cos\gamma\cos(\gamma+\varphi_1) - \sin\gamma\sin(\gamma+\varphi_1)\right] = 0 \qquad (15)$$

Or

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$$\cos[\gamma+(\gamma+\varphi_1)]=0$$

From here we get the following.

$$\gamma=\frac{\pi}{4}-\frac{\varphi_1}{2}. \qquad (16)$$

where γ-is half of the disc sharpening angle, grad.

If we put certain values of φ_1 (25-35°) in expression (16) [4, 5], we find that the sharpening angle of the disc is in the range of 55-65°. We take the average value of these, i.e. 2γ =60°. Because in this case, the equally acting part of the forces *N* and *F* (Fig. 2) is directed close to the vertical, and good compaction of the soil is ensured.

RESULTS

Based on compaction, grinding and leveling of the flakes rolled by the plug body, the assembly of working parts of the device should consist of a roller equipped with working disks with a smooth surface and a leveler-densifier of plates forming a fine layer installed on the back. In order to ensure high-quality crushing and compaction of the soil at the depth where the seeds of repeated crops are thrown, the depth of the roller discs is 3-5 cm, the diameter is at least 40 cm, the sharpening angle is 60□, the thickness is 3 cm, and the vertical force falling on the roller should be around 56-3.58 kN, when aggregated with a three-body plow.

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