ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF ARTIFICIAL INTELLIGENCE

ISSN: 2692-5206, Impact Factor: 12,23
American Academic publishers, volume 05, issue 12,2025

Journal: https://www.academicpublishers.org/journals/index.php/ijai

THEORETICAL CALCULATION OF PARAMETERS FOR ENERGY-RESOURCE EFFICIENT FLAT-CUTTING AND DEEP-LOOSENING SIDE WORKING IMPLEMENTS

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Abstract. The article presents the results of our theoretical studies on the justification of the parameters of the side working bodies of the energy-resource-saving flat-cutter-deep-loosener. According to the results of theoretical studies, it was established that the angle of entry of the lateral working bodies of the flat-cutter-deep-loosener into the soil should be 30°, the angle of installation relative to the direction of movement - no more than 40°, the working width - no more than 19.9 cm, and the working surface width - no less than 9 cm.

Keywords: energy-resource-saving flat-cutter-deep-loosener, side working bodies, angle of entry into the soil, angle of installation relative to the direction of movement, working width and working surface width.

One of the most important ways to reduce energy consumption during tillage is to ensure that the working bodies of tillage machines and implements operate under open cutting conditions, i.e., they interact with layers with open furrows or loosened zones on the sides. However, the processes of soil deformation and destruction under the influence of working bodies under open cutting conditions have not been sufficiently studied both in our country and abroad. Therefore, scientific research in this area is still relevant today and is of great importance in improving energy-saving soil cultivation technologies.

Based on the foregoing, as a result of our research, an energy-resource-saving flat-cutter-deep-loosener has been developed, which consists of a V-shaped frame equipped with a mounting device, central, right and left side working bodies installed on it, and support wheels.

The central working body of the deep ripper, i.e., the first to be located on its frame, is made in the form of a ripper tine, and the right and left side working bodies are equipped with a chisel and are made in the form of a one-sided trihedral wedge, the working surface of which is directed towards the working body located in front of it. During the operation of the flat-cutter-deep-loosener, its central working body acts on the solid soil and therefore operates in closed cutting conditions, while the lateral working bodies, since the working surface is made in the form of a one-sided trihedral wedge directed towards the working body located before it, deform the soil towards the zone processed by the working body preceding it and operate in open cutting conditions, which leads to a reduction in energy and resource consumption.

This article presents the results of our theoretical research on substantiating the parameters of the side working bodies of the energy-resource-saving flat-cutter-deep-loosener.

The investigated parameters of the side working bodies of the energy-resource-saving flat-cutter-deep-loosener are (Fig. 1):

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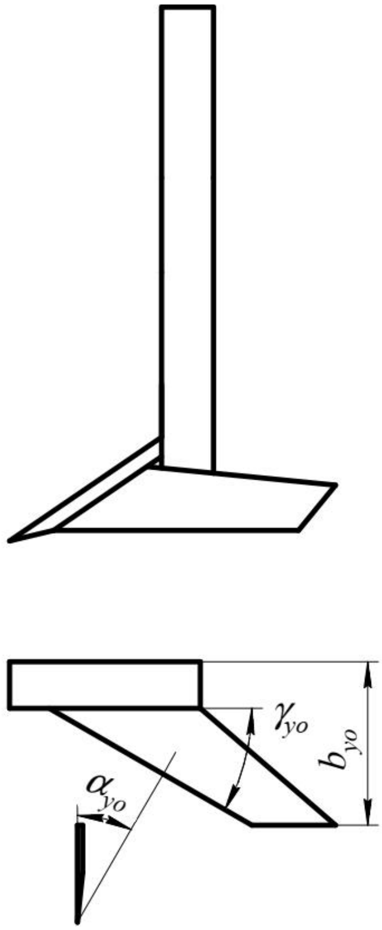

Figure 1. Studied parameters of lateral working bodies

γ_{yo} - angle of installation of the lateral working body relative to the direction of movement, °;

α_{yo} - angle of entry (crushing) of the lateral working body into the soil, °;

B_{yo} - working width of the lateral working body, m;

b_{yo} - width of the working surface of the lateral working body, m.

Research on the determination of these parameters was conducted using studies previously conducted by A.Tukhtakuziev, K.B.Imomkulov, B.U.Tashpulatov, I.I.Abdimominov, and others [1-6].

The angle of installation of the side working parts relative to the direction of movement is determined from the condition of sliding cutting of plant residues and weed roots encountered on their path according to the following expression [7]:

$$\gamma_{yo} = \frac{\pi}{2} - \varphi_{i\max}, \qquad (1)$$

where φ_i max - the maximum value of the friction angles of plant residues and weed roots against the edges of the lateral working bodies, °.

Based on the literature data, assuming φ_i max = 50° [8-10], according to expression (1), we determine that the installation angle of the side working parts relative to the direction of motion should be no more than 40°.

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The angle of entry (crushing) of the side working bodies into the soil is determined from the condition of high-quality crushing with minimal energy consumption according to the following expression [7]:

$$\alpha_{yo} = \arcsin \quad -\sin\left(\varphi_1+\varphi_2\right)+$$

$$+\sqrt{\sin^2\left(\varphi_1+\varphi_2\right)+ \quad 2+\frac{1}{2}\cos\left(\varphi_1+\varphi_2\right) \quad 1+\cos\left(\varphi_1+\varphi_2\right)} \quad :$$

$$: \ 2+\frac{1}{2}\cos\left(\varphi_1+\varphi_2\right) \quad , \qquad (2)$$

where φ_1, φ_2 are the angles of soil friction against the working surface of the lateral working bodies and against the soil, respectively, o.

Substituting into expression (2) the values φ_1 = 25-30°, φ_2 = 40-45° [8, 9], we determine that the angle of penetration of the side working bodies into the soil should be within 25-32°. As the final result, we will take this angle as 30°.

The working width of the side working parts is determined using the following expression from the condition that they operate under fully open cutting conditions:

$$B_{yo} \quad \frac{1}{2} \quad \sqrt{p^2a^2-\left(pa-m\right)^2+\frac{1}{16} \quad p^2c-4\left(pa-m\right) \quad ^2} \ +$$

$$+\frac{p^2c-4\left(pa-m\right)}{4} \quad , \qquad (3)$$

here $$a = k_s; \qquad (4)$$

$$c = 4q_0k_s\frac{tg\alpha_{yo}\sin\left(\alpha_{yo}+\varphi_1\right)}{\cos\varphi_1\cos\left(\gamma_{yo}+\varphi_1\right)}; \qquad (5)$$

$$p = \frac{\cos\left(\gamma_{yo}+\varphi_1\right)\cos\varphi_1 ctg\alpha_{yo}}{q_0\sin\left(\alpha_{yo}+\varphi_1\right)}; \qquad (6)$$

and

$$m = \frac{2h\cos\left(\gamma_{yo}+\varphi_1\right)}{\cos\frac{1}{2}\left(\alpha_{yo}+\varphi_1+\varphi_2\right)\cos\varphi_1}, \qquad (7)$$

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where q_0 is the coefficient of bulk compression of the soil, N/m^3.

Taking q_0 = 1·107 N/m3 and substituting the above values of ks, αyo, φ_1, φ_2, γyo and h into expressions (4) - (7) and then substituting the determined values of a, c, p and m into (3), we determine that the working width of the side working bodies should be no more than 19.9 cm.

To determine the width of the working surfaces of the lateral working bodies, let us consider the process of soil destruction on its side (Fig. 2). It is known that when a three-sided wedge operating in the open cutting process moves from position I to position II, the soil is previously compressed under its influence, and when the stresses generated in it reach a critical value, it breaks down along the displacement plane ABCD at an angle to the direction of movement. With the subsequent movement of the working body, this split angle rises along its working surface and the side is shifted towards the loosened area. At the same time, the next part of the soil is compressed and decomposed with the S step. According to the research conducted by A.Tukhtakuziev and K.Imomkulov[1]:

$$S = 2\sqrt{\frac{k_s\, B_{yo} \cos\varphi_1}{q_0 \cos\left(\gamma_{yo} + \varphi\right)_1 tg\alpha_{yo} \sin\left(\alpha_{yo} + \varphi_1\right)}}\,\frac{\cos\varphi_1}{\sin\gamma_{yo}}. \qquad (8)$$

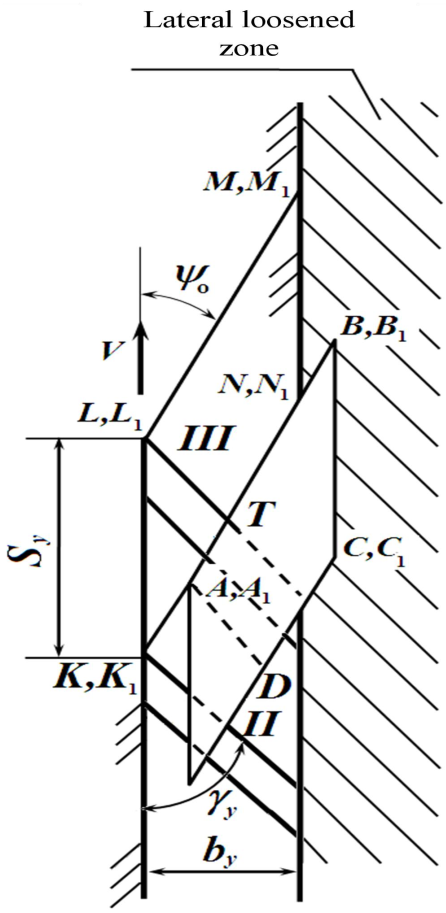

Figure 2. Diagram for determining the width of the working surface of the side working body

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To ensure soil fragmentation according to the scheme shown in Figure 2, the following condition must be met:

$$b_{yo}\cos\alpha_{yo} \quad S\sin\gamma_{yo}\,. \qquad (9)$$

From this

$$b_{yo} \quad \frac{S\sin\gamma_{yo}}{\cos\alpha_{yo}}\,. \qquad (10)$$

or taking into account (8)

$$b_{yo} \quad 2\sqrt{\frac{k_s\; B_{yo}\cos\varphi_1}{q_0\cos\left(\gamma_{yo}+\varphi_1\right)tg\alpha_{yo}\sin\left(\alpha_{yo}+\varphi_1\right)}}\;\frac{\cos\varphi_1}{\cos\alpha_{yo}}\,. \qquad (11)$$

Substituting the above and determined values of ks, B_{yo}, φ_1, q0, γ_{yo} and α_{yo} into this expression, we determine that the width of the working surface of the lateral working body should be at least 9 cm.

Conclusion. According to the theoretical studies conducted to determine the parameters of the side working bodies of the energy-resource-saving flat-cutter-deep-loosener, in order for the side working bodies to ensure high-quality soil crushing with minimal energy consumption, complete loosening of the soil layer being cultivated by it, and the working body to prevent the release of the lower moist layer of soil onto the field surface, the angle of its entry into the soil should be 30o, the angle of installation relative to the direction of movement should be no more than 40o, the width of its coverage should be no more than 19.9 cm, and the width of its working surface should be at least 9 cm.

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