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THE ORETICAL SUBSTANTIATION OF PARAMETERS OF THE COMBINED ASSEMBLY

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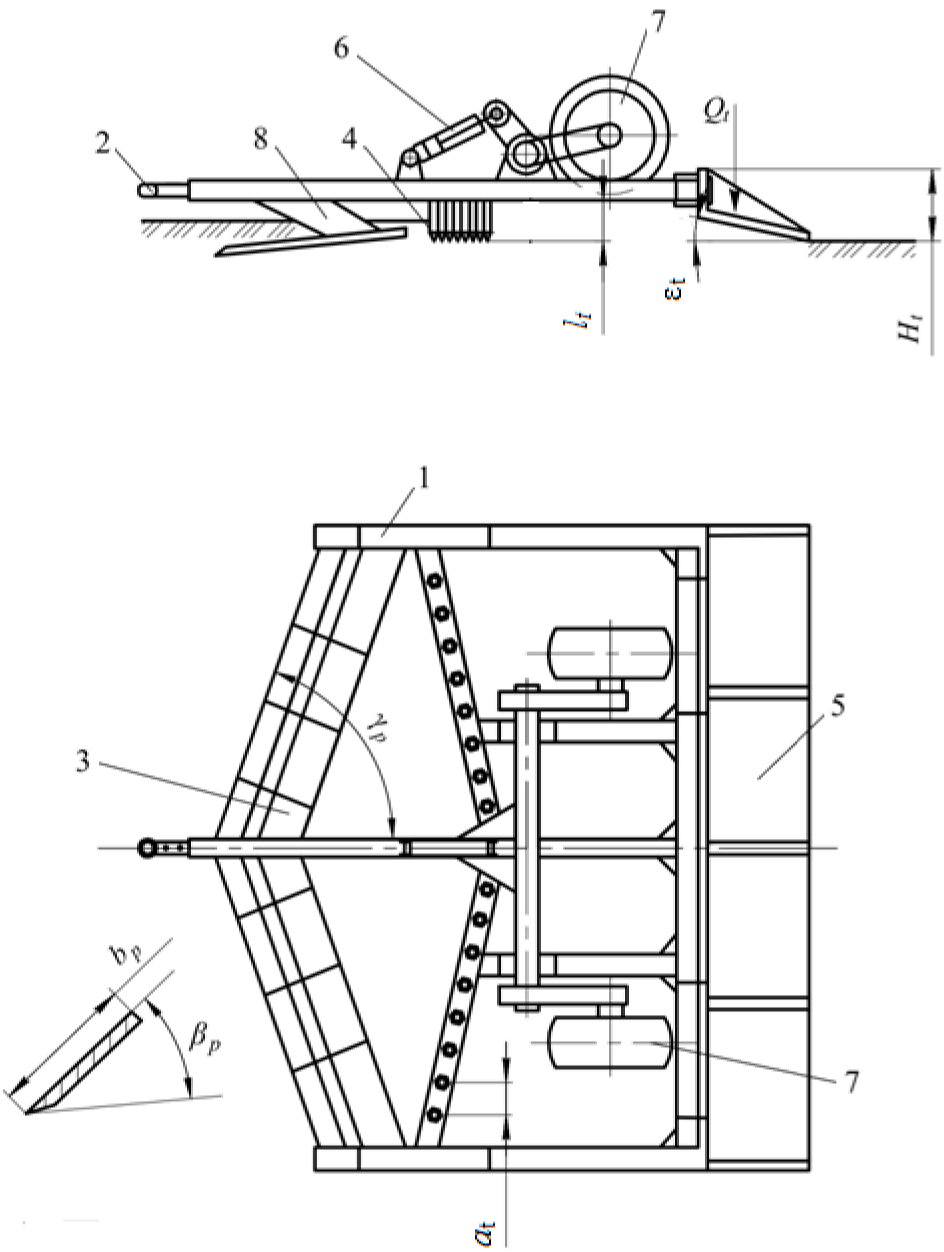
Abstract

The article highlights the development of combined machine that prepares land for planting in one pass, and theoretical researches based on the theory of wedge and the basic rules and laws of agricultural mechanics to justify its structure, work process and parameters. According to the results of the research, in order for the combined aggregate to perform the specified technological process at the speed of 1,7-2,2 m/c with low energy consumption, the installation angle of its flat cutting blade in relation to the direction of movement is in the range of 27°-30°, the crumbing angle is 24°-29° range, the width of the working surface is at least 6,2 cm, the length of the tines is 16-20 cm between them, the width of their tracks is at most 13,4 cm, the height of the leveler-compactor is at least 23,5 cm, the angle of installation of the compactor part relative to the horizon, the angle of installation relative to the direction of movement of the flat cutting claw is in the range of 27°-30°, each meter of coverage of leveler-compactor vertical loading given to width 2,16-2,67 kN should be between.

Keywords

soil preparation for sowing, combined aggregate, structure, operation process, parameters, theoretical researches, analytical formulas for parameter determination.

Introduction. In our Republic, soil preparation for sowing in spring season has been carried out by using separate aggregates for various agrotechnical operations such as plowing, chiseling, and harrowing. These operations require excess labor, fuel, and other expenditures that lead to the loss of soil moisture, disruption of soil structure, and excessive compaction. Based on the above, combined aggregate capable of preparing the soil for sowing in single pass has been developed (see figure 1).



1 - frame; 2 – connecting part to tractor; 3 – flat-cutting blade; 4 - tines; 5 - leveler-compactor; 6 - hydraulic cylinder;

7 - supporting wheel; 8 - vertical blade.

Figure 1. Structural scheme and parameters of the combined aggregate.

Combined aggregate is equipped with three rows of operating components, with flat cutting blades in the first row, tines in the second row, and leveler-compactor in the third row. Its operational process is as follows: as the aggregate moves across the field, the flat cutting blades loosen the soil to specified depth, cutting through any loosened pieces encountered along the way and leveling the surface of the working area by scraping in low spots. The tines break down the large clods created under the influence of flat cutting blades, while the leveling-compacting device finalizes the leveling and compaction of the field surface.

The results of theoretical research implemented to determine the parameters of developed combined aggregate are specified in the article.

Research materials and methods. Researches were implemented by using the fundamental principles and laws of the theory of wedge agriculture mechanics and farming technology.

Research results and discussion. The following are considered as primary parameters that affect to performance indicators of the combined assembly:

γ_p –installation angle of the flat cutting blade relative to its direction of motion, °,

β_p –crumbing angle of flat cutting blade,°;

b_p – width of working surface of the flat-cutting blade, m;

l_t – length of tines, m;

a_t – width of the trace formed by tines, m;

H_t – height of the leveler-compactor, m;

ε_t – Installation angle of the compaction section of the leveling-compaction device in comparing with horizontal position, °;

Q_t – Vertical load applied to leveler-compactor unit, N.

Let's determine the installation angle of flat-cutting blade relative to its movement direction based on the following condition [1]:

$$\gamma_p = \frac{\pi}{4} - \frac{\varphi_1}{2}, \quad (1)$$

where φ_1 is friction angle between the soil and the working surface of the flat cutting blade, °.

When the condition (1) is fulfilled, the likelihood of soil adhering to the working surface of flat cutting blade and forming clumps in front of it is reduced, thereby decreasing its drag resistance to the blade's movement.

The crumbing angle of the flat cutting blade is determined when the following formula, on the condition that it efficiently crumbs the soil with minimal energy consumption [2]:

$$\beta_p = \arcsin\{\{\sin^2(\varphi_1+\varphi_2)+[2+\frac{1}{2}\cos(\varphi_1+\varphi_2)]\times$$
$$\times[1+\cos(\varphi_1+\varphi_2)]\}^{\frac{1}{2}} - \sin(\varphi_1+\varphi_2)/[2+\frac{1}{2}\cos(\varphi_1+\varphi_2)]\}, \quad 2)$$

where φ_2 is inside soil friction, that means friction angle onto the soil, °.

The following formula has been derived for the purpose to determine **width of the working surface of the flat cutting blade**, under the condition that the layer being processed is completely fractured.

$$b_p \geq \sqrt{\frac{2}{q_o}} \frac{1}{\cos\frac{1}{2}(\varphi_1 + \varphi_2 - \beta_p)} \{k_c h \cos\varphi_1 \cos\varphi_2 \times$$

$$\times [ctg\beta_p + tg\frac{1}{2}(\beta_p + \varphi_1 + \varphi_2)]\}, \qquad (3)$$

where q_o is volumetric crushing coefficient of the soil processed by flat-cutting blades, N/m³;

k_c is relative resistance of soil to displacement, N/m²;

h is the processing (sink into the soil) depth of the flat cutting blade into the soil, m.

Length of tines depends on processing depth, so let's determine it base on the following empiric formula [3]:

$$l_t = (2{,}0 - 2{,}5)h_t, \qquad (4)$$

where h_t – processing depth of the tines, m.

Width of the tines' traces was determined according to the following formula, provided that they fully process onto the field surface [4]

$$a_t \leq 2h_t tg\psi_v, \qquad (5)$$

where ψ_v is lateral fracture angle of soil,°.

In order to determine **the height of leveler-compactor**, the following formula was derived on condition that it does not exceed the soil top dumped in front of it.

$$H_t \geq 4\sqrt{\frac{Z_n l_n}{\pi} tg\mu + h_\kappa \frac{\rho_1 - \rho_o}{\rho_1}}, \qquad (6)$$

in this case Z_n, l_n is the height and length of irregularities formed on the soil surface by flat-cutting blades and tines of the combined aggregate in respectively, m;

μ is slope angle to the horizon of dumped soil in front of the leveller-compactor aggregate,°;

h_κ is processing depth of the combined aggregate, m;

ρ_o is soil density processed by flat-cutting blades and tines of the combined aggregate, kg/m³;

ρ_1 is soil density after compaction by the leveler-compactor, kg/m³.

Installation angle of the leveler-compactor of leveler relative to horizontal was determined under the condition that the interaction time with the soil particles will have minimum value during the working process, resulting in the following formula:

$$\varepsilon_t = arctg\frac{1-\sin\varphi_1}{\cos\varphi_1}. \quad (7)$$

When this condition is fulfilled, soil adhesion to compacting part of the leveler-compactor and excessive crushing in front of it are not observed, which result in in reliable technological process with minimal energy consumption.

The vertical load applied to the leveler-compactor was determined under the condition that the soil processed by the flat cutting blade and tines is compacted to the required level under its influence, and the following expression was obtained:

$$Q_t = 0{,}5q_o'[1+k_vV_a(\cos\varepsilon_t - \sin\varepsilon_t tg\varphi_1)\sin\varepsilon]\frac{B_a h_k^2}{\sin\varepsilon_t}(1-\frac{\rho_o}{\rho_1}), \quad (8)$$

in this case q_o' is the volumetric crushing coefficient of soil processed by the flat-cutting blades and tines, N/m³;

k_v is coefficient that accounts for variations in the soil's volumetric crushing coefficient based on its deformation rate, s/m;

V_a is the velocity of aggregate movement, m/s;

B_a is the movement velocity of combined aggregate, m.

(8) By dividing the formula base on coverage width of the aggregate, let's determine the equivalent vertical load corresponding to coverage width of single unit of the leveler.

$$Q_t^s = 0{,}5q_o'[1+k_vV_a(\cos\varepsilon_t - \sin\varepsilon_t tg\varphi_1)\sin\varepsilon]\frac{h_k^2}{\sin\varepsilon_t}(1-\frac{\rho_o}{\rho_1})^2. \quad (9)$$

Calculations carried out in accordance with formulas based on information as specified in literatures and the following formula values were accepted as shown: [5-8] φ_1=30-35°, φ_2=35-45°, q=5×10⁶ N/m³, k_c=4×10⁴ Pa, h=0,1 m, h_t=0,08 m, ψ_v=40°, z_n=0,1 m, l_n=0,15 m, μ=30°, h_k=0,1 m, ρ_o=900 kg/m³, ρ_1=1200 kg/m³, q_o'=3×10⁶ N/m³, k_v=0,1 s/m, (1)-(7) and (9) indicate that at movement velocities of 1,7-2,2 m/s, the combined aggregate can efficiently perform the designated technological process with minimal energy consumption, under the following parameters:

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installation angle of its flat cutting blade relative to the direction of movement should be within the range of 27°-30°; the loosening angle should be between 24°-29°; width of working surface should be at least 6,2 cm; the tines length should be between 16-20 cm; width of the tines traces should not exceed 13,4 cm; height of leveler-compactor should be at least 23,5 cm; and installation angle of compacting part of the leveler-compactor relative to horizontal should be within 27°-30°; similar to installation angle of the flat-cutting blade. Vertical load applied per meter of coverage width of the leveler-compactor should be in the range of 2,16-2,67 kN.

Conclusion.

Developed combined aggregate is capable for efficiently performing the designated technological process with minimal energy consumption at movement velocities of 1.7-2.2 m/s, under the following parameters: the installation angle of its flat-cutting blade relative to movement direction should be within the range of 27°-30°; loosening angle should be between 24°-29°, the working surface width should be at least 6.2 cm; length of tines should be between 16-20 cm; the width of tines traces should not exceed 13.4 cm; height of the leveler-compactor should be at least 23.5 cm; and installation angle of the compacting part relative to horizontal should match as in the flat-cutting blade, at 27°-30°. The vertical load applied per meter of coverage width of leveler-compactor should be maintained within the range of 2.16-2.67 kN.

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