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Study on combined machine for the subsurface soil treatment

Kh Ravshanov[1*], F Mamatov[1,2], B Mukimov[1], R Sultonov[1], A Abdullayev[1], and G Murtazaeva[3]

[1]Karshi branch of Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 180119 Karshi, Uzbekistan
[2]Karshi Engineering Economic Institute, 180100 Karshi, Uzbekistan
[3]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 100000 Tashkent, Uzbekistan

[*]Email: ravshanovhamroqul@mail.ru

Abstract. The purpose of the study is to substantiate the relative position of the working bodies of a combined machine for non-fall tillage of winter crops. The design scheme and the principle of operation of the combined machine are given. The basic principles and methods of classical mechanics, mathematical analysis and statistics were used in this study. It is established that the most optimal design scheme of a combined machine for non-tillage of the soil and its preparation for sowing of repeated crops is considered to be a scheme consisting of non-tillage cases with crushers, a battery with cut-out spherical disks and a roller. According to the results of theoretical and experimental studies, it was found that with a longitudinal distance between the shaft-free bodies of 40 cm and a transverse distance of 90 cm, a longitudinal distance from the toe of the ploughshare to the center of the support wheel of 50 cm and a longitudinal distance from the toe of the ploughshare of the shaft-free body to the axis of rotation of the cut-out spherical disk of 120 cm, a longitudinal distance from the axis of rotation of the cut-out spherical disk to the center of the roller of 75 cm, high-quality tillage with minimal energy costs is provided.

1. Introduction

Logical and inquire about works are being carried out within the world to create modern logical and specialized establishments of high-performance and resource-saving advances and specialized implies for planning the soil for cotton sowing. In

this respect, it is fitting to conduct logical inquire about on the advancement of a combined machine for planning the soil for sowing agrarian crops.

Blevins and Frye [1], Jamaletdinov [2], Mamatov [3-28], Mirzaev were engaged in the creation of combined machines for non-fall tillage, as well as preparing it for sowing in one pass through the field and substantiating the parameters of their working bodies [5-13, 15-22, 24, 29], Ergashev [3, 7, 13, 24], Chuyanov [6, 28], Fayzullaev [6, 26, 30, 31], Ravshanov [5-7, 21, 26, 27, 31, 32] and others. The machines and tools created as a result of these studies are used in agricultural production with certain positive results. However, in these studies, the issues of substantiating the design schemes of machines and the parameters of working bodies for non-fall tillage with simultaneous preparation for sowing are not sufficiently studied. Currently, for sowing crops, the technologies of basic tillage and preparing it for sowing include agrotechnical measures consisting of several operations performed separately and sequentially, which lead to loss of moisture, excessive compaction of the soil and destruction of its structure, delaying the sowing period, as well as increasing fuel consumption, labor and other costs.

The subject of this research is the forms of interaction of the working bodies of combined machines and their parameters, the designs of changes within the vitality and quality markers of combined machines, depending on the parameters of their working bodies and the speed of the unit. Consequently, the purpose of the study is to substantiate the relative position of the working bodies of a combined machine for non-fall tillage of winter crops.

2. Methods

The basic principles and methods of classical mechanics, mathematical analysis and statistics were used in this study.

The authors propose a technology for preparing the soil from under grain crops for sowing repeated crops in one pass (Figure1). This technology consists of the following operations: a vertical cut of the soil and plant residues is made with disc knives 1 in front of the rack of the non-shaft housing 2, loosening the soil layer with a thickness of 25-27 cm and crumbling its middle part with non-shaft housing 2, equipped with crumblers 3. Disk batteries additionally crumble the soil and mix the top layer of soil, as well as create a mulching layer from plant residues, the roller coming from behind levels and compacts the soil surface.

The implementation of the above technological processes by a combined machine in one pass allows you to preserve soil moisture in the area of re-sowing crops, improves the processes of aeration and infiltration, eliminates the development of erosion, prevents soil compaction, dramatically reduces the time of preparing it for sowing, reduces material energy resources during processing and preparing it for sowing, i.e. by reducing the number of passes of the unit in the field, minimal tillage is provided.

The combined machine for the implementation of the proposed technology (Figure 2) consists of a frame 1, support wheels 2, disc knives 3, non-shaft

housings 4 with crushers 5, batteries with cut-out spherical disks 6 and a roller 7.
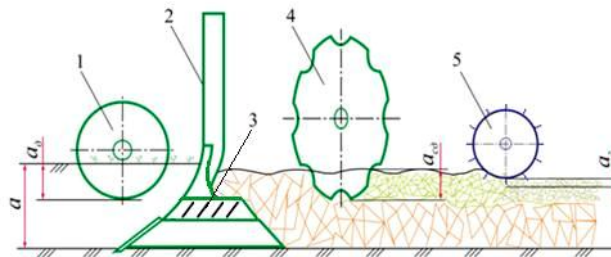
Figure 1. Technology of non-fall tillage: 1 – disc knife; 2 – non-fall body; 3 – cutter knives; 4 – spherical disc battery; 5 – roller
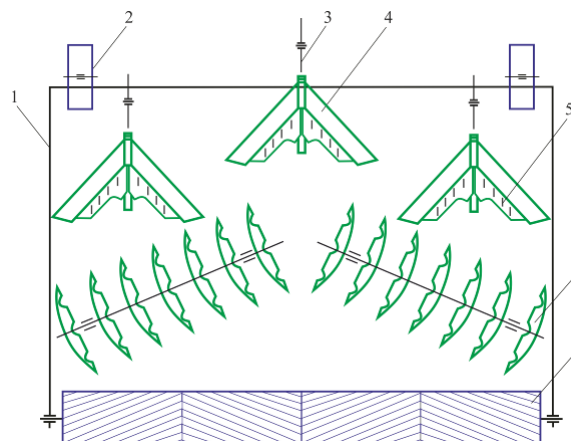
Figure 2. Design diagram of the combined machine: 1 – frame; 2 – support wheel; 3 – disc knife; 4 – shaft-free housing; 5 – knife crumbler; 6 – battery with cut-out spherical disks; 7 – roller

The quality indicators of the combined machine mainly depend on the relative position of the working bodies and the support wheels.

The longitudinal distance from the toe of the ploughshare of the non-shaft housing to the center of the support wheel was determined from the condition of unhindered displacement of the deformed soil by the non-shaft housing, i.e., the exclusion of contact of the deformed soil of the rim of the support wheel

$$L_{m_2} \geq \sqrt{R_\kappa^2 - (R_\kappa - h_\kappa)^2} + a\cos\gamma \; tg \frac{1}{2}(\varepsilon + \varphi_1 + \varphi_2), \qquad (1)$$

where R_κ – the radius of the support wheel, m; h_κ – the depth of immersion of the wheel in the soil, cm; a – the depth of processing of the shaft-free housing, m; γ – the angle of the ploughshare to the direction of movement, degree ε – the angle of the ploughshare to the bottom of the furrow, degree; φ_1 va φ_2 – respectively, the

external and internal angles of soil friction, degree.

According to expression (1) at R_k=25 cm, h_k=2 cm, a=25 cm, $\gamma = 42°$, $\varepsilon = 35°$, φ_1=30° and φ_2=40°, the longitudinal distance from the ploughshare toe to the center of the support wheel must be at least L_{tg} = 46.2 cm.

The longitudinal distance between the non-shaft bodies (Figure 3) was determined from the condition of excluding the superimposition of the deformed soil zone of the rear body on the soil deformation zone of the front body by the following expression

$$L_k \geq \frac{a}{\sin \gamma}\left[tg\frac{1}{2}(\varepsilon + \varphi_1 + \varphi_2) + tg\theta\right],\qquad(2)$$

where θ – is the angle of lateral cleavage of the soil, degree.

By expression (2) at a=25 cm, γ=42°, ε=35°, φ_1=30°, φ_2=40° and θ=25° the longitudinal distance between the shaft-free bodies must be at least L_k=38.6 cm.
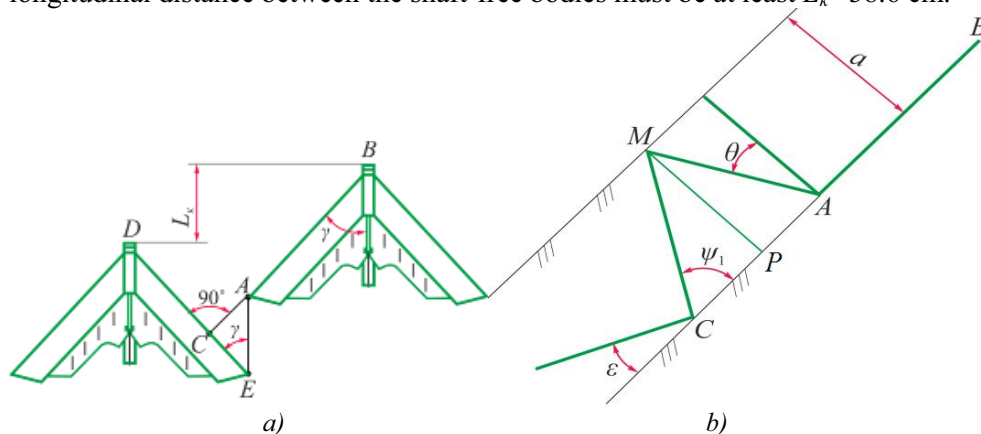
Figure 3. Schemes for determining the longitudinal distance between the bodies without overturning (*a*) and the deformation of the soil under the influence of the body (*b*)

The longitudinal distance from the tip of the ploughshare of the shaft-less body to the axis of rotation of the disk working body (Figure 4) was determined by the following expression

$$L_{kd} = 0{,}8b_k ctg\gamma + b_l\cos\alpha + \frac{V_p\cos(\arcsin tg\alpha\cos\varepsilon)}{g} \times$$

$$\times\sqrt{\frac{\sin^2\gamma\cos^2(\varepsilon+\varphi)}{\cos^2\varphi} + \cos^2\gamma}\,\{V_p tg\alpha\cos\varepsilon\sqrt{\frac{\sin^2\gamma\cos^2(\varepsilon+\varphi)}{\cos^2\varphi} + \cos^2\gamma} +$$

$$+\sqrt{V_p^2(tg\alpha\cos\varepsilon)^2[\frac{\sin^2\gamma\cos^2(\varepsilon+\varphi)}{\cos^2\varphi} + \cos^2\gamma] + 2gb_l\sin\varepsilon]}\}\times$$

$$\times \cos arctg \frac{(1-\cos\varepsilon)tg\gamma}{1+tg^2\gamma\cos\varepsilon} + atg\alpha + \sqrt{2Rh-h^2}\sin\mu, \tag{3}$$

The longitudinal distance from the tip of the ploughshare of the shaft-less body to the axis of rotation of the disk working body (Fig. 4) was determined by the following expression

According to expression (3) at b_k=45 cm, γ=42°, b_l=120 mm, α=25°, V_p=2.0 m/s, ε= 35°, g=9.8 m/s^2, φ=30°, a=25 cm, R=710 mm, h=12 cm, and μ=21°, the longitudinal distance from the tip of the ploughshare of the non-shaft housing to the axis of rotation of the disk working body is L_{kd}=118 cm.
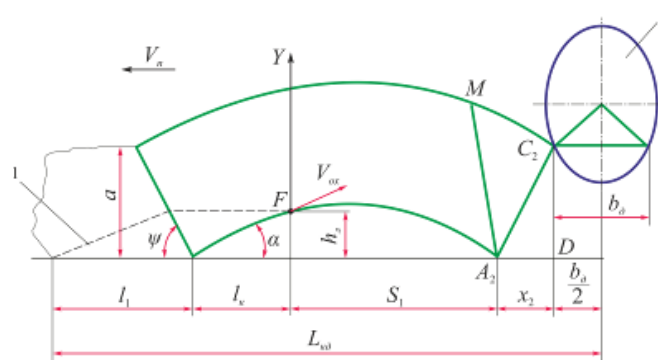
Figure 4. Scheme for determining the longitudinal distance from the toe of the ploughshare of the shaft-free housing to the axis of rotation of the disk working body: 1 – ploughshare;
2 –disk working body

To determine the rational values of the transverse and longitudinal distance between the buildings, a laboratory and field installation was made.

3. Results and Discussions

As can be seen from the graph (Figure 5), at all three working depths, as the transverse distance between the overturned bodies increased from 90 cm to 110 cm, the degree of soil erosion decreased according to the laws of the sunken parabola and then remained unchanged. This can be explained by the increase in the cross-sectional area of the soil, which is treated with non-overturning bodies. For example, when the transverse distance is 90 cm, the degree of soil compaction at all three tillage depths, i.e. the amount of fractions smaller than 50 mm, is 77.5-84.0%. An increase in the transverse distance from 100 cm to 120 cm resulted in a decrease of 5.3-7.4%.
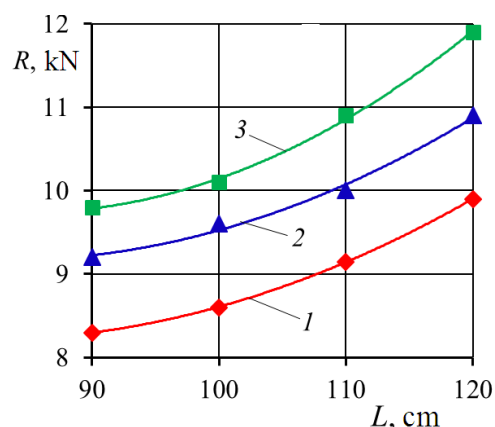
As can be seen from the graph in Figure 6, with all three machining depths, the tensile strength of non-overturned enclosures increases according to the laws of the sunken parabola as the transverse distance increases from 90 cm to 120 cm. This can be explained by the fact that non-overturning bodies move from a semi-open

area to a completely closed area during operation. Experiments have shown that when the transverse distance between the bodies without a tipper is 90 cm, the soil particles pass between the working bodies without compression and accumulation. When the transverse distance between the hulls without the overturner was 100 cm or more, the hulls operated in a completely closed zone, leaving untreated space between them and the required agro-technical parameters were not met.

Thus, the quality characteristics and traction resistance of non-overturned housings are directly related to the transverse distance between them, and this distance should be in the range of 90 cm to ensure high working quality with low energy consumption in the technological process.
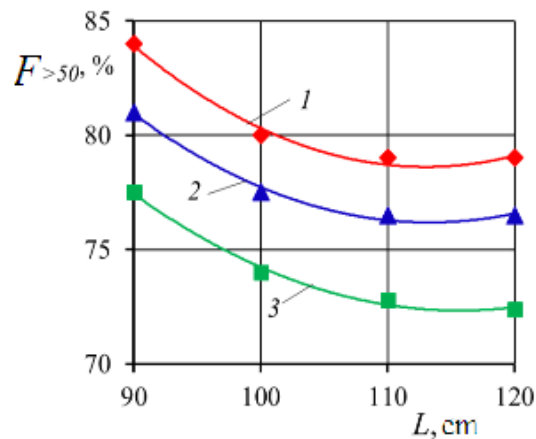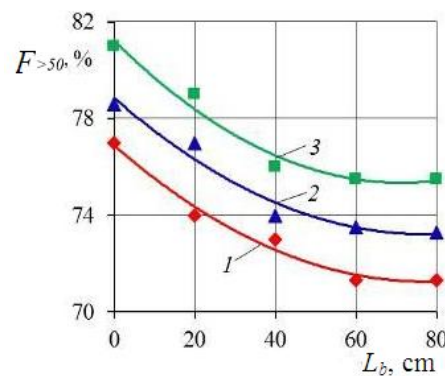

Figure 5. Graphs of the degree of crumbling of the soil ($F<50$) depending on the transverse distance of the bodies (L) at 1, 2 and 3, respectively, $a = 20$, 25 and 30 cm

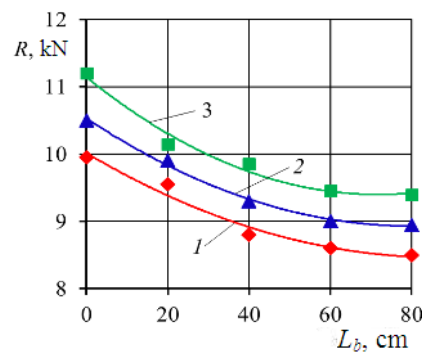**Figure 6.** Graphs of the dependence of the traction resistance of the housings (R) on the transverse distance of the housings (L) at 1, 2 and 3, respectively, $a = 20$, 25 and 30 cm

As can be seen from the graph (Figure 7), the increase in the longitudinal distance between them from 0 to 80 cm at processing depths of 20, 25 and 30 cm of the crusher-free hulls leads to a decrease in the degree of soil erosion according to the laws of the sunken parabola. led to a decrease in the amount of fractions smaller than 50 mm in size. The increase in longitudinal distance from 40 cm to 80 cm had little effect on this figure. When the longitudinal distance is less than 40 cm, it is observed that the pallets touch each other when working with the right and left non-overturning bodies. As a result, the soil particles collided with each other due to the speed of work. This improved the compaction of the soil at small values of longitudinal distance. At all three tillage depths, the longitudinal distance was less than 40 cm and the soil compaction rate was more than 70%.

Figure 7. Graphs of the degree of crumbling of the soil ($F<50$) depending on the longitudinal distance of the bodies (L_b) at 1, 2 and 3, respectively, $a = 20$, 25 and 30 cm

Figure 8. Graphs of the dependence of the traction resistance of the housings (R) on the longitudinal distance of the housings (L_b) at 1, 2 and 3, respectively, $a = 20$, 25 and 30 cm

As can be seen from the graphs shown in Figure 8, at all three machining

depths, when the longitudinal distance between the non-overturning bodies was 0-80 cm, their gravitational resistance decreased according to the law of the sunken parabola. When the longitudinal distance between the bodies without the inverter is 0 cm, its gravitational resistance is 8.6%, 15.6%, 18.9% and, respectively, compared to the longitudinal distance of 20, 40, 60 and 80 cm. 20.7% large. This is due to the fact that when the longitudinal distance between the overturned hulls is close, the bulkheads increase due to soil deformation during processing and the cross-sectional area of the hull increases due to the interlocking of the ground between the hulls. When the longitudinal distance between the bodies without overturning is 0-40 cm, the tensile strength is reduced by 15.6%. This can be explained by the fact that as the longitudinal distance between the non-overturning bodies increases, the next non-overturning body changes from a closed shear condition to a semi-open shear condition during the interaction with the soil.

Hence, it was found that with a longitudinal distance between the non-fallow buildings located in pairs-symmetrically 0.4 m and a transverse distance of 0.9 m, high-quality implementation of the technology of pre-sowing non-fallow tillage and preparing it for sowing repeated crops with minimal energy costs is provided.

4. Conclusions

The most optimal design scheme of a combined machine for non-tillage of the soil and its preparation for sowing of repeated crops is considered to be a scheme consisting of non-tillage housings with crushers, a battery with cut-out spherical disks and a roller.

According to the results of theoretical and experimental studies, it was found that with a longitudinal distance between the shaft-free bodies of 40 cm and a transverse distance of 90 cm, a longitudinal distance from the toe of the ploughshare to the center of the support wheel of 50 cm and a longitudinal distance from the toe of the ploughshare of the shaft-free body to the axis of rotation of the cut-out spherical disk of 120 cm, a longitudinal distance from the axis of rotation of the cut-out spherical disk to the center of the roller of 75 cm, high-quality tillage with minimal energy costs is provided.

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