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Research Article

Design Parameters of Disc Levellers for the Track Loosener of a Two Pass Mounted Harrow

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Abstract

The article examines the improvement of the working process of a two-track mounted harrowing unit designed to improve the quality of surface soil tillage and reduce operational costs. The main shortcomings of two-track tooth harrows used under the conditions of the Republic of Uzbekistan are analyzed, including the need to periodically stop the unit for manual removal of weeds and plant residues from the working bodies, increased labor requirements, difficulties in transportation from one field to another, low maneuverability, and large overall dimensions. To eliminate these shortcomings, a two-track mounted harrowing unit has been developed, consisting of a frame, a three-point hitch, tooth harrows connected to the frame by chain links, support skids, and track loosening devices. The track loosener includes a loosening tine and disk levellers mounted on the frame by means of a parallelogram mechanism. Based on the laws and principles of agricultural mechanics, theoretical studies were conducted on the interaction of the disk levellers with the soil, and their main structural and technological parameters were substantiated. It was established that, to ensure the required levelling of the soil surface, the diameter of the disk levellers should be at least 21 cm, the working width should be 12 cm, the installation angle relative to the direction of travel should be 37°, the radius of curvature of the working surface should be 32 cm, and the distance between the disks should be 26 cm. The obtained results can be used in the development, design, and manufacture of two-track mounted harrowing units.

Keywords

Two-pass Harrowing, Track Loosener, Disc Leveller, Working Width, Installation Angle, Disc Curvature

1. Introduction

To ensure the required quality of work under the conditions of our republic, ridge formation across all areas is carried out using a two-pass method—specifically, by employing spike-tooth harrows arranged in two rows [1]. The harrowing units consist of two rows of harrows coupled to the towing equipment. However, such harrowing units suffer from the following serious drawbacks:

1) To clear weeds and crop residues stuck in the harrows, the unit is stopped and cleaned manually. Two to four additional workers are assigned to each unit for this pur-

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pose. According to the Center for Certification and Testing of Agricultural Machinery and Technologies (CCTTSS), the time spent clearing crop residues and weeds from the harrows accounts for 30% of the shift time. [2, 3];

2) To move from one field to another, the unit is disassembled, transported using additional vehicles, and reassembled. According to KHTTSSM data, this process requires 4.5 man-hours [2, 3];
3) Two-track harrows have poor maneuverability, are inconvenient to operate, and are bulky.

All this leads to reduced productivity and work quality of harrowing units, as well as increased fuel consumption and higher labor and other costs.

To overcome the aforementioned drawbacks, improve performance and crop yields, and reduce energy and material consumption, a mounted two-pass harrow unit has been developed. [4].

It is equipped with a mounted unit comprising a frame and spike-tooth harrows connected to it by chains. Mounted on the frame are support skids—which maintain the unit at a set height above the field surface—and working elements for loosening the soil in tractor wheel tracks (i.e., track looseners). These track looseners consist of a scraper-type loosening tine and disc levelers, connected to the harrow unit's frame via a parallelogram mechanism.

During the operation of a dual-pass harrowing unit, track looseners break up the soil compacted by the tractor wheels using a loosening tine, while disc levelers smooth out the irregularities created by the loosening tine.

This article presents the results of theoretical studies aimed at substantiating the parameters of the disc levelers for the track loosener of a newly developed mounted double-track harrowing unit.

2. Literature Review

An analysis of scientific and technical literature indicates that the issue of loosening soil within wheel tracks is addressed by many researchers. Researchers abroad [5] propose using C-shaped and S-shaped tines to loosen the soil in the wheel tracks. However, their main drawback is the failure to level the soil surface in the loosened zone, which negatively affects the quality of subsequent sowing.

The design according to Inventor's Certificate No. AS1532017 [6] incorporates working elements for cutting furrows ahead of the front wheel, as well as devices for loosening and backfilling the furrow left by the wheel behind the rear wheels. Despite the complexity of its action, this unit is characterized by high material and energy intensity.

The design developed by V.V. Mizkov et al. [7] features a device equipped with rippers and a V-shaped leveler mounted on hinges with elastic elements. A drawback of this system is the significant difference in density between the tilled and undisturbed soil layers, which hinders the development of a deep root system.

Research by Yu. A. Savelyev et al. [8] proposes a design in which rippers and blades are arranged in a staggered pattern. Despite the attempt to improve soil pulverization, the authors note inadequate tillage quality and the displacement of large clods to the surface.

The design covered by Patent No. AS2282958 [9] features a two-row arrangement of rippers and a gang of disc blades. Analysis of this configuration indicates that the soil does not achieve optimal density after processing, and the vertical blades contribute to the accumulation of large clods in front of the rippers.

The device proposed by R. M. Musin [10] comprises rippers with shanks arranged in two tiers, as well as disc gangs. The main drawback of this design is its tendency to become clogged with crop residues and weed roots, which reduces process quality and increases energy consumption.

The design proposed by A. P. Shadrin [11] features an adjustable mounting system for the working element sections. However, experimental data indicate that the passage of the ripper results in the formation of large clods, which increase the overall resistance of the implement.

3. Analysis of Methods for Mitigating Soil Compaction

Study [12] proposes a mitigation method in which rippers are installed both ahead of the running gear (for preliminary loosening) and behind it (for final loosening of the compacted zone). This reduces the depth of compaction propagation and improves the degree of soil fragmentation. This dual-action principle is considered promising.

The design developed by M. U. Kaipov [13] focuses on adjusting the working elements to match the tractor's track width. Its drawbacks include reduced tractor functionality due to a rigid connection to the hitch linkages, as well as the formation of surface irregularities after the pass, which negatively affects subsequent sowing operations.

4. Materials and Methods

The track loosener design comprises a sweep positioned within the tractor track and two discs for the lateral displacement of soil (Figure 1). Principles of agricultural mechanics regarding crop residue cutting and the geometry of a penetrating disc [14-21] are applied. The initial parameters are as follows: crop residue diameter $d = 0.02$ m; disc penetration depth $h = 0.05$ m; friction angles $\varphi_1 = 30°$ and $\varphi_2 = 40°$; soil spreading width of the sweep $b_u = 0.12$ m; clearance angle $\varepsilon = 3°$; and sharpening angle $i = 20°$. Angular values are expressed in degrees, and linear dimensions in meters.

The minimum diameter, based on the condition of severing plant residues at the selected friction angles, is estimated using the expression [14-19]:

$$D \geq \frac{d[1+\cos(\varphi_1+\varphi_2)]+2h}{1-\cos(\varphi_1+\varphi_2)} \quad (1)$$

Here, φ_1 and φ_2 are the friction angles of plant residues against the blade and the soil surface, respectively. The working width of the disk, bd, must be no less than the soil spreading width, b_u:

$$b_d \geq b_u \quad (2)$$

For a partially submerged disk, the geometric width of cut at an angle α to the direction of motion is equal to [15-20]:

$$b_d = 2\sqrt{h(D-h)}\sin\alpha \quad (3)$$

Substituting (3) into condition (2) yields the minimum permissible angle; the expression is applicable when D > h and $b_u \leq 2\sqrt{[h(D-h)]}$:

$$\alpha_{\min} = \arcsin\left(\frac{b_u}{2\sqrt{h(D-h)}}\right) \quad (4)$$

To evaluate the curvature of the working surface, the half-arc angle φ_e, the clearance angle ε, and the sharpening angle i were used [15-19]:

$$\varphi_e = \arctan\left(\frac{D\tan(\alpha-\varepsilon)}{2\sqrt{Dh-h^2}}\right) - i \quad (5)$$

$$R = \frac{D}{2\sin\varphi_e} \quad (6)$$

The transverse distance between the discs B is determined taking into account the width of the share b and the width of the layer displaced by it:

$$B = b + b_u \quad (7)$$

In the scheme under consideration, the sweep width *b* is treated as a parameter. The value *B* = 0.26 m corresponds to *b* = 0.14 m; for a different sweep width *B*, a recalculation is required. All trigonometric functions in the calculation were evaluated using values converted from degrees to radians.

5. Results

According to formula (1), the minimum diameter is 0.1928 m. The adopted design diameter of 0.21 m satisfies the cutting condition; however, at α = 37°, formula (3) yields b_d = 0.1077 m, which is less than the required 0.12 m. Increasing the angle to 42.2° with D = 0.21 m ensures a capture width of approximately 0.120 m. Another option maintains α = 37° and increases D to 0.25 m, resulting in b_d = 0.1204 m. These calculations are presented in Table 1.

Table 1. *Internally consistent calculated parameters of the disc levelers.*

Option	Diameter D, m	Angle α, °	Working width bd, m	Radius R, m
А	0,21	42,2	0,120	0,261
Б	0,25	37,0	0,1204	0,363

Note. The radius R is calculated using formulas (5) and (6); its value depends on the selected setting angle. For both variants, the distance between the discs is B = b + 0.12 m.

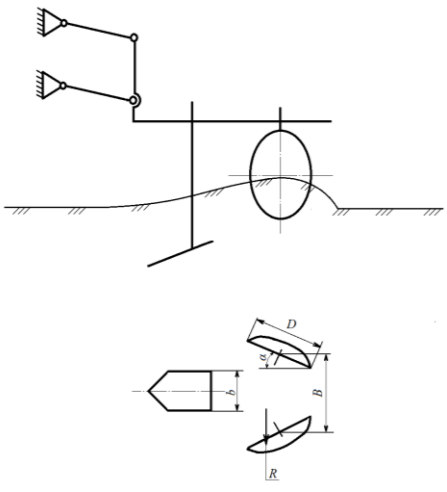


Figure 1. *Diagram of the track loosener and geometric parameters of the discs.*

6. Discussion

The resulting options demonstrate that the diameter and the installation angle must be determined in conjunction. At D = 0.21 m, an angle of α = 37° does not provide coverage for the width b_u = 0.12 m. To maintain the 37° angle, the calculation requires a diameter D of at least 0.249 m; a value of D = 0.25 m is adopted in Table 1. Changing the diameter also alters the radius of curvature of the working surface, as calculated using formulas (5) and (6).

Relationships (1)–(7) describe the geometric compatibility of the parameters but do not account for soil moisture and particle-size distribution, implement speed, edge wear, draft resistance, or the variation in crop residue thickness. The next step involves fabricating working elements with the selected dimensions and measuring ridge height, soil density (before

and after the pass), the proportion of uncut residues, and specific resistance. Without such measurements, it cannot be asserted that any of the variants improves performance quality or reduces energy consumption.

7. Conclusions

Based on the initial conditions, the calculated minimum disc diameter is 0.193 m. Geometrically compatible configurations include, for instance, D = 0.21 m at $\alpha \geq 42.2°$ and D = 0.25 m at $\alpha = 37°$. For the latter option, the calculated radius of curvature of the working surface is approximately 0.363 m. The inter-disc spacing should be determined after measuring the width of the tine, using the formula B = b + 0.12 m. This result reflects theoretical conditions and requires experimental verification.

Abbreviations

φ The Friction Angles

Author Contributions

Abdusalim Tukhtakuziyev: Data curation, Formal Analysis, Funding acquisition, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing

Otaboyev Mukhammad Fakhriddin o‘g‘li: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Abdusalim Tukhtakuziyev is a Doctor of Technical Sciences, Professor, Head of the Laboratory for Pre-sowing Soil Preparation and Seeding Mechanization, Research Institute of Agricultural Mechanization, Uzbekistan. His scientific research has primarily focused on agricultural machinery, soil tillage and pre-sowing soil preparation, the development and improvement of working bodies of agricultural implements, and the mechanization of agricultural production. He has participated in the development of various agricultural machines and working mechanisms and is listed as an inventor or co-inventor of several agricultural machinery patents.



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Research Field

Abdusalim Tukhtakuziyev: Agricultural Engineering; Agricultural Machinery and Mechanization; Soil Tillage Machinery; Agricultural Machine Design; Mechanization of Viticulture; Working Bodies of Agricultural Machines; Soil–Machine Interaction; Agricultural Technology and Machinery Optimization

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Ermatov Valijon Abdivaitovich: Agricultural Engineering; Agricultural Machinery and Mechanization; Agricultural and Reclamation Machinery; Mechanization of Viticulture; Rotary Working Bodies; Soil–Machine Interaction; Vineyard Machinery; Agricultural Machinery Design; Agricultural Technology; Optimization of Machine Parameters