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Development of the Technological Scheme of the Combined Frontal Plough and the Justification of the Parameters of Disc Working Bodies

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ABSTRACT

It has been established that there is a need for regular inclusion of soil plowing in the process of minimum tillage. The need for regular inclusion of soil plowing in the process of minimum tillage has been established. A technological scheme for a combined machine has been developed, and a combined front plough for smooth plowing capable of performing both basic and surface soil tillage in a single pass has been proposed. Several geometric, operational, and technological parameters of the proposed plow working body have been determined. The feasibility of using a combined front plough for smooth plowing has been confirmed.

Introduction

Agricultural machines and tools produced in the territory of the former USSR, which still occupy a significant share in the machinery park of Armenia, are of low quality. Their reliability and durability are inferior to their global counterparts (Tsench, et al.,2018).

The creation of high-quality agricultural machinery will become a reality if it is based on modern methods developed in various countries around the world, accurate calculations, thorough research, and advanced cutting-edge technologies. Moreover, it is essential to maintain a high level of operational reliability of agricultural machines in the future, based on the latest methods of technical maintenance and repair and a base of technical means (Zimin and Smetnev, 2015).

Materials and methods

At the current stage of agricultural production, minimum tillage is being emphasized, as it ensures the reduction of operational costs and soil erosion by combining the necessary technological processes of soil cultivation (Belousov and Trubilin, 2017).

In recent years, there have been frequent attempts to eliminate the plowing process in the context of applying new technologies (Kulikova and Zagudaeva, 2019).

However, the results of numerous studies have confirmed that completely removing plowing from technological processes is a categorical mistake. This is because it results in the lower layers of the soil / deeper than 15cm / not being cultivated at all, with only the top layer of soil being utilized. Although plowing is a very heavy and energy-intensive process, like many researchers, we also support the idea that plowing should be carried out periodically, once every 3-4 years. This approach allows the lower layers of the soil to participate in cultivation while helping to restore the fertility of the surface layers (Varin and Iskhakov, 2023). In all cases, one of the requirements of new technology is to reduce the number of passes of technical means in the field, which must be performed imperatively (Alekseeva, et al., 2014). Therefore, in the case of including the plowing technological process, the number of passes should be reduced, and minimum tillage should be ensured. This means that plowing should be combined with the following technological process, namely, performing both the primary and surface soil cultivation in one pass of the aggregate. The solution to this problem is to create a combined agricultural machine that simultaneously performs plowing to a depth of 25-30 cm and surface cultivation to a depth of 15-20 cm. For this approach to solving the problem, we have chosen the plow + disc harrow combination.

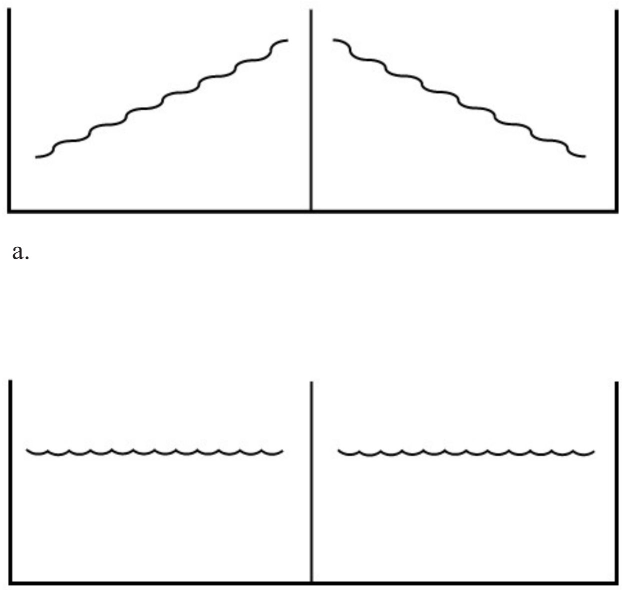
The main disadvantage of such combined machines is their high traction resistance. To reduce this, modifications have been made to the structure of the harrow and the plow, as well as optimization of the technological parameters of the working organs (Tonapetyan, et al., 2021).

Creating a machine combined with traditional plows involves a series of complexities. The issue is that the moldboard of traditional plough has a sequential arrangement, leading to their considerable length, which will increase even further when combined. As a result, we will end up with a very long aggregate, which becomes impractical in the soils of Armenia. This is due to the small sizes of the plots, the frequency of turns and maneuvers, the fragmented nature of the fields, the inconvenience of moving the aggregate from one field to another, and other factors (Mirzakhodjaev, et al., 2018).

Results and discussions

Considering the above-mentioned factors for designing a combined plow, we have decided to focus on the design of a front plough, which has an advantage over traditional plows in that its tines are arranged broadly, which in turn gives both the plow and the aggregate compact dimensions. In addition, the tines and other working organs have a symmetrical arrangement, which is important for the course stability and technological consistency of the aggregate. The main disadvantage observed in the front plough is its high traction resistance, which comes from the fact that these plows, in addition to their main moldboards, also have auxiliary working organs like turner plows, which assist in turning the soil in their furrow.

The main moldboards of the front plow have a curved surface, which, as is well known, turns the soil well but does not crumble it effectively. With this type of plow, the furrows often turn out very rough, especially in soils with lots of weeds and particularly in harder soils. The turning of the furrow by two working organs often causes disruptions, which further increases the traction resistance and, in some cases, can even halt the process. To make it combined, the auxiliary working organs were initially removed, resulting in the furrows not being completely turned into their furrow. Since the two adjacent moldboards work in opposition, the incompletely turned furrows in the central part of the tines create a ridge-shaped soil heap, as shown in Figure 1a.

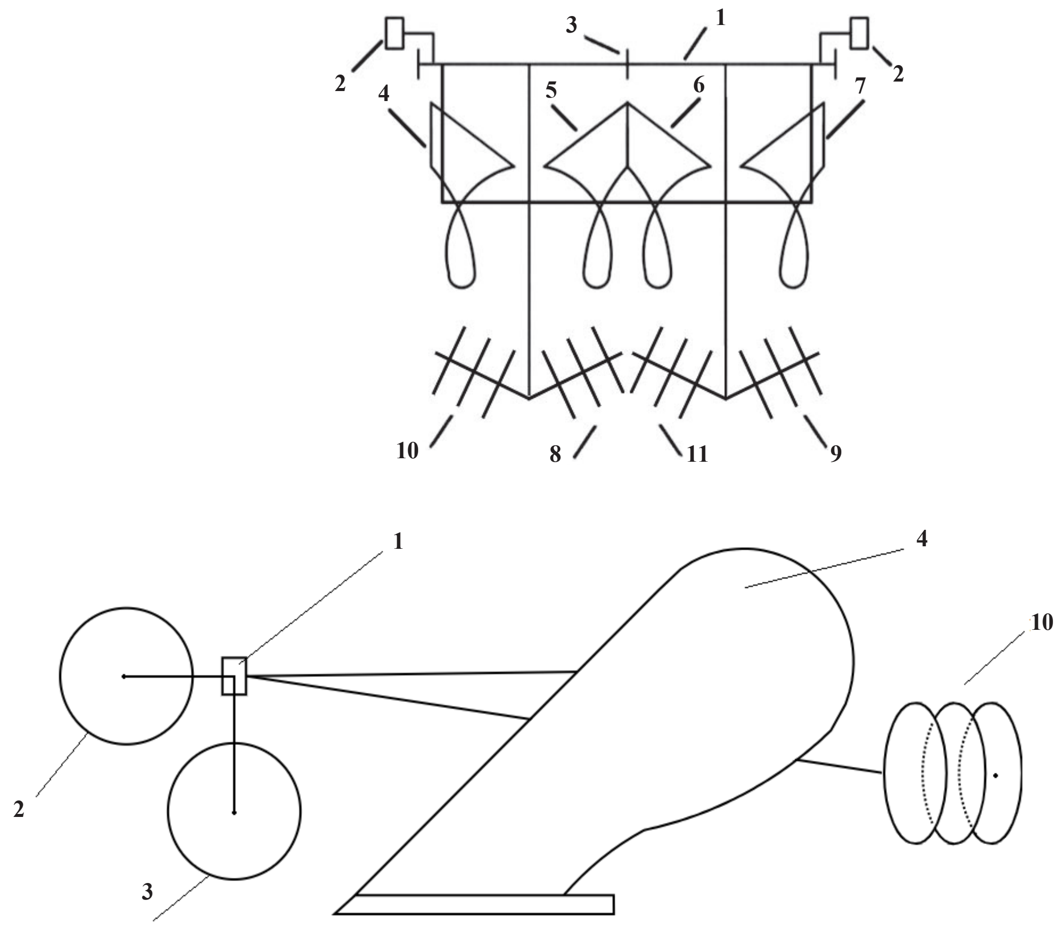


a.

b.

Figure 1. Appearance of the Furrows. *a. After the passage of the moldboards of the combined plow, b. After the passage of the disc coulters of the combined plow (composed by the authors).*

a.



b.

Figure 2. Front plough for combined smooth plowing:
a. Horizontal Projection,
b. Profile Projection: *1. Frame, 2. Supporting Wheels, 3. Blades, Right-turning 4. Left-turning and 6 Left-turning 5. Moldboards, 6. Left-turning, 7 moldboards, Right-turning 8. Left-turning, 9. Left-turning, 10. Disc Coulters, 11. Disc Coulters (composed by the authors).*

To spread and simultaneously crumble the soil, combat weeds, and achieve a smooth, crumbled surface, disc coulters are placed following the moldboards in the combined plow (Figure 2) (Yesoyan , et al., 2023).

From a technological and energy perspective, the removal of the turner plow from the design of the front plough and the inclusion of disc coulters is justified. Additionally, the proposed machine achieves a seedbed-ready surface in a single pass, making its use justified from a practical standpoint (see Figure 1b). This proposed machine has been granted a patent in Armenia (RA Patent No. 846Y, (2023)).

The parameters of the moldboards with a curved surface in the front plough have not changed, so the basis for the parameters of the working organs of the combined machine has been the disc coulters only.

The front plough for combined smooth plowing has four-disc coulters, each located across the width of one tine.

The parameters we have focused on for the disc coulters are:

- the inclusion width -$B_{coulter}$
- the working depth – h
- the number of discs in the coulter - n and the distance – d
- the angle of attack of the disc – α
- the radius of curvature of the disc – R
- the diameter of the disc - D.

Each coulter "services" one tine, so the width of inclusion of one coulter should equal the width of inclusion of one tine of the front plough, which is 45 cm.

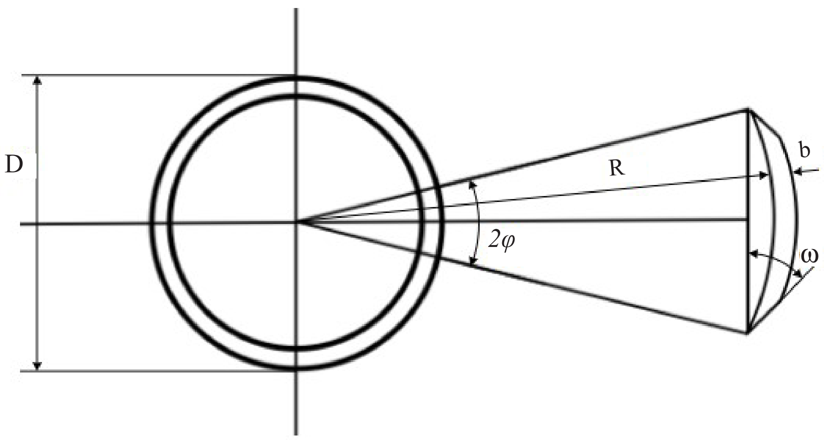


Figure 3. Spherical disc 1. There is a relationship between the central angle 2φ, the diameter of the disc D, and the radius of curvature R of the disc *(Panov A.I., Puzikov S.S., 2018)*.

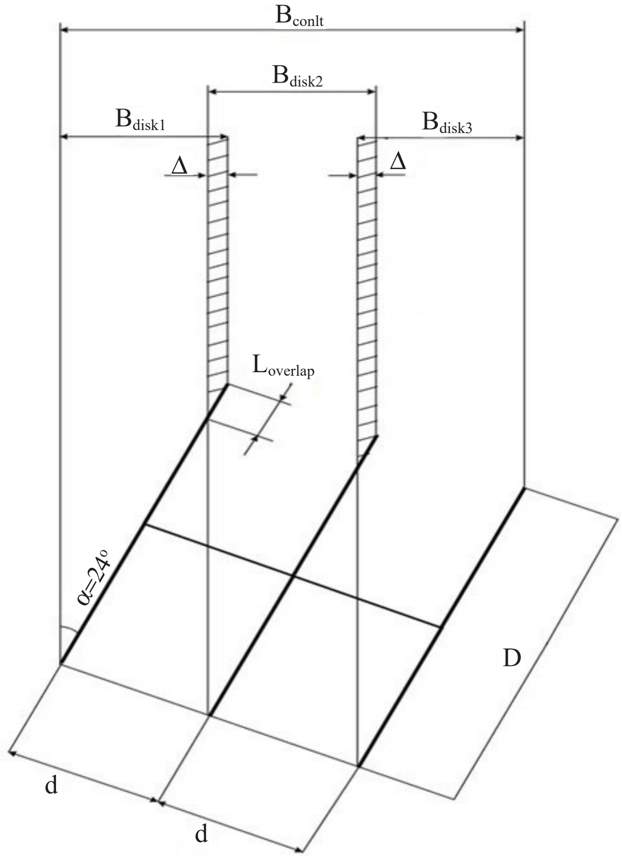


Figure 4. Schematic for Determining the Inclusion Width of the Disc and Coulter.*(composed by the authors)*.

Here, the problem boils down to determining the inclusion width of one disc of the coulter, based on which the number of discs in the coulter will be determined. To determine the width of inclusion of the disc, it is first necessary to determine the diameter of the disc and the angle of attack.

We are choosing a spherical disc (see Figure 3).

$$D=2\sin\varphi\ R. \quad (1)$$

The discs are standardized and the most commonly used diameters are 450, 510, and 600 mm (GOST 198-75). Considering that after the passage of the moldboards of the front plough, a ridge-shaped surface is formed, which needs to be smoothed by the selected discs, we choose the largest available diameter for the discs, $D=600$ mm, which according to GOST, has a thickness of $b=4.0$ mm.

The aforementioned GOST also standardizes certain geometric parameters of the disc, specifically the angle φ. For the selected disc diameter, φ is set at 25°. Consequently, the radius of curvature of the disc will be calculated as R = D/$(2\sin\varphi) = 710$ mm.

The angle of attack of the disc depends on the depth of cultivation. According to GOST, for cultivation depths of 10 to 20 cm, the angle of attack of the disc is set between 6 and 24 degrees (GOST 10267-69).

Considering that in this case the discs are required to process a ridge-shaped surface, we choose the largest prescribed depth, $h=hmax=20\ cm$, which corresponds to the maximum angle of attack $\alpha = 24°$ (Figure 4).

Therefore, the inclusion width of 1 disc will be:

$$B_{isc} D sin\alpha = 0.6*sin24 = 24 \text{ cm}. \quad (2)$$

The inclusion width of the disc coulter will be determined by the following formula.

$$B_{coulter} = nB_{disc} - (n-1)\Delta = nDsin\alpha - (n-1)\Delta, \quad (3)$$

where. n is the number of discs in the coulter, Δ and is the overlap measurement between consecutive discs.

The inclusion width of a single disc coulter should be equal to the width of the inclusion of one moldboard, which is 0.45 m. Therefore, from equation (3), we get the result.

$$n\, Dsin\alpha - (n-1)\Delta = 0.45. \quad (4)$$

Assuming the overlap size to be $\Delta=12$ cm (to avoid untreated areas during turns), the number of discs in one coulter will be $n=2.75$. We round this to $n=3$ discs. Using Figure 4, we can determine the distance between the discs in the coulter.

$$d = (D - L_{overlap})cot\alpha = (D - \Delta/sin\alpha)cot\alpha =$$
$$= (0.6 - 0.12/sin24)cot24 = 0.67 \text{ m}. \quad (5)$$

Conclusion

1. Minimum tillage technologies do not typically include plowing. However, considering the serious negative consequences of omitting it, it is proposed to include plowing in the pre-sowing cultivation process at certain intervals, specifically once every 3-4 years. One of the ways to achieve this is through the creation of a combined machine based on plow bases.

2. The construction of the combined plow is structurally suitable for execution on the bases of front ploughs, which have compact dimensions and symmetrical and broad arrangement of moldboards.

3. On the base of the PFN-2A front plough, has been proposed combined plough for smooth plowing. Its turner plows have been removed from the structure, and disc coulters have been added with the following parameters:

- Number of coulters: 4,
- Type of disc: Spherical,
- Width of inclusion of one coulter: 45 cm,
- Diameter of the disc: 600 mm,
- Angle of attack of the disc: 24°,
- Number of discs in the coulter: 3,
- Radius of curvature of the disc: 710 mm,
- Distance between discs in the coulter: 67 cm.

4. The use of the combined front plough is justified from technological, energetic, and practical perspectives.

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