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Increase of rotation angle of soil layers during plow operation

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Abstract. One of the advantages of plowing is the ability of the plow to hide the weed seeds deep into the soil. The depth of the embankment exceeds 10-12 cm, from there the weeds can not rise to the surface of the soil. They perish halfway. But for this, it is necessary to wrap the soil layers at an angle close to 180 °. Modern ploughs can not turn the layers of soil at an angle of more than 135 °, therefore the plow is required to be equipped with additional working elements. The aim of the study is to create an adaptation to the plow to expand the furrow before laying the next soil layer. In a wide furrow, the formation will completely tip, the previous layer will not interfere with it. The device is a set of vertical shields. Each shield is fixed behind the working body of the plow. It is installed with an angle of attack of 20-25 ° to move the previous layer to expand the furrow by 10-12 cm. The model and industrial samples of the plow have shown improved agrotechnical indicators. The average angle of the formation rotation was 177 °, the burial of plant residues in the soil increased from 61 to 99%. The field surface with blocks more than 5 cm decreased from 36.3 to 13.4%, the height of the ridges decreased from 7 to 4 cm. The force of soil pressure on the shield was measured by a strain gage. It is 130-330 N depending on the depth of processing and the speed of movement. The increase in power costs for the four-hull plow was 190-750 W. The coulters on the plow are unnecessary, and this saves energy more than its increase for shields.

1. Introduction

An ancient method of basic soil cultivation by plowing with the turnover of the layers in recent years has found an alternative in the form of light-weight processing of the surface layer at a shallow depth. The competition of these methods consists in comparing the positive and negative aspects of both technologies. After plowing, a looser structure and a smaller bulk density of soil are observed [1]. Deeper embedding of plant residues contributes to an increase in the rate of their decomposition in a favorable environment of microbial activity [2]. With increasing depth of processing, plant residues will be buried in the soil deeper. It was noted that according to the soil biomass coverage index, the disc harrow showed 43.8%, and the combined cultivator showed 87.8% [3]. The seeds of weeds, together with the plant remains, must also be deeply embedded in the soil so that they can not germinate. They must die half way to the surface of the soil. The decrease in the number of weeds after autumn plowing was noted in [4]. No cultivator can be compared with a plow to kill weeds without the use of herbicides. Agricultural workers in Russia call the plow as a field doctor. Plowing with the turnover of layers is considered as the main method of controlling weeds [5]. According to this indicator, the use of the plow replaces two or three harrow applications in the spring period [5]. It was noted in [6] that during the 2-year period plowing reduced the number of amaranth weeds in the field by 98%. Since the mid-2000s, the average amount of herbicide applied and the associated environmental load, measured by the EIQ indicator, haы increased both in GM-modified and traditional cultivars. The main reason for these changes is the increase in the number of herbicide tolerant weeds species [7]. The negative side of deep plowing is the large expenditure of energy and fuel, and this affects the pollution of the atmosphere by exhaust gases [3]. Thus, the main treatment of the soil with the turnover of the layers suppresses the weeds and thereby reduces the need for herbicides. Of all the tools for tillage, only plows are able to turn the soil layers. But for the suppression of weed plants, a full turnover of layers is needed to hide the fallen weed seeds to an inaccessible depth of more than 10-12 cm. Plows, available in the world market, overturn the soil layers at an angle of not more than 140°. Only the front plows, which appeared in Russia at the end of the 20th century, can overturn each layer by 180 °, since they act on the formation on both sides and cause it to rotate in its furrow. All other models of plows turn layers by rolling. Thus the turn appears incomplete, as the previous layer partially hangs over a furrow and prevents the next layer to finish the turn. But the front plows have the disadvantage that their technological passages for the soil are often clogged, especially when there are lots of weeds and with an increase in the depth of plowing, therefore such plows are not widely distributed. The aim of the study is to create a plow capable to overturn completely soil layers in a simple way with preliminary expansion of each furrow before laying the next layer. In a wide furrow, the layers lie down, not interfering with each other, so they turn completely and form the leveled surface of the plowed field.

2. Materials and methods

To expand the furrow, it is possible to use a disc organ [9] or a vertical shield. These additional operating elements are installed behind each working housing [10]. Figure 1 shows the location of the disc bodies attached to the plow dumps.

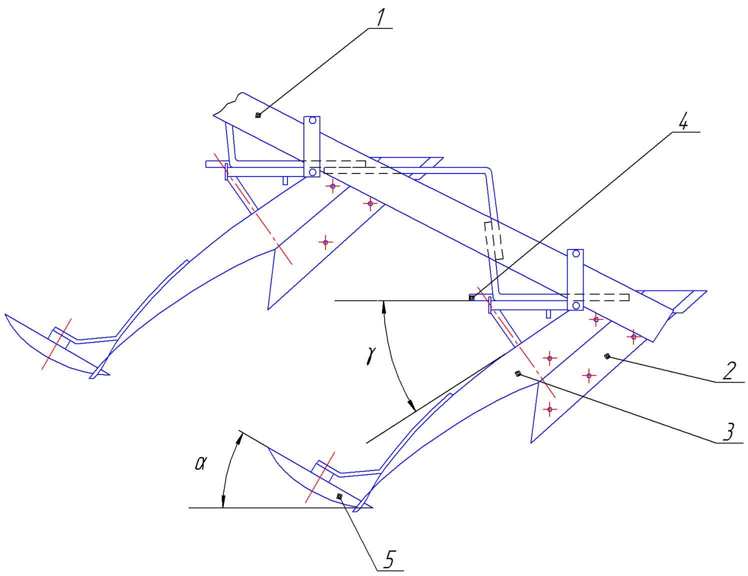

Figure 1. Additional disc bodies on the plow: 1 - the main beam of the plow; 2 - plowshare; 3 - plow blade; 4 - side board; 5 - additional disc organ

They cut off the overhanging parts of the soil layers and thus expand the furrows. Another way to broaden the furrow is to move the previous layer to the right side, that is, closer to the plowed part of the field (Figure 2). For this purpose, a vertical shield is installed behind each working hull, which widens the furrow. In a wide space, the layer can turn completely, that is, at an angle of 180 °. This method of increasing the angle of rotation was simpler and cheaper than the use of discs, so an industrial plow pattern was designed and built (Figure 3). In field experiments, the quality of plowing was recorded in accordance with agrotechnical indices and the force of pressure of soil on a shield was measured using a load cell.

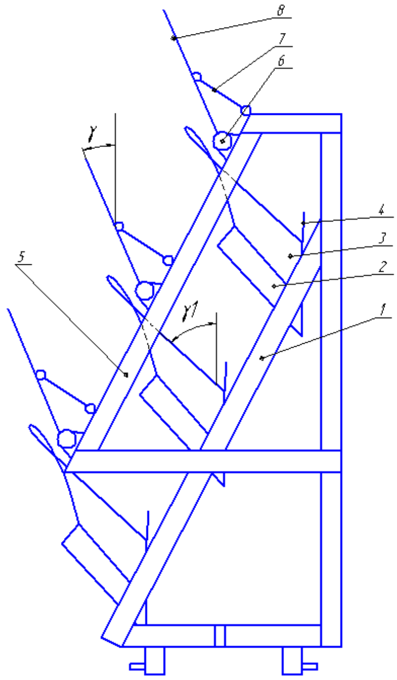

Figure 2. Placement of additional shields on the frame of the mock-up pattern of the plow:
1 – plow frame; 2 – plowshare; 3 – plow blade; 4 – side board; 5 – additional plow beam; 6 – swivel axis; 7 – shield support; 8– shield

Figure 3. Industrial prototype of plow with complete turnover of soil layers

3. Main results of the study

Field experiments with mock and industrial plow samples provided a better quality of plowing compared to the work of a conventional plow without shields. Table 1 shows some of the agrotechnical indices of its operation when plowing to a depth of 25 cm with an average speed of 1.72 m / s.

Table 1. Quality indicators of plowing with a device for increasing the angle of rotation of layers in comparison with the work of a conventional plow

Indicators	Plow with adaptation	Plow without adaptation
Speed of the plow, m / s	1.72	1.72
Working width of one working body, m	0.35	0.35
Average depth of tillage, cm	25.1	25.2
The average height of the crests of the soil after plowing, cm	4.1	7.0
Part of the soil surface with blocks more than 5 cm,%	13.4	36.3
Angle of rotation of layers, degree	177	130
Implantation of plant residues in soil,%	99	61

The use of an experimental plow with an adaptation for a more complete turn of soil layers has a significant advantage over a conventional plow. This advantage lies in a more even surface of the field, in the reduction of the number of large blocks and in a more complete closure of the plant residues. Additional energy costs associated with the use of shields were measured during plowing. The force with which the shield acts on the soil in a perpendicular direction was subjected to measurement. For this purpose, a strain gauge was used. It turned out that this effort depends on the depth of plowing and the speed of plough:

$$P = 920.43\, a^2 + 69.47\, a^2 v^2,$$

where P is the force of the shield pressure on the soil, N;
a – depth of plowing, m;
v – speed of plow, m / s.

This relationship is presented graphically in Figure 4. The graph of the normal pressure force shows that the force of the normal shield pressure on the soil varies according to the polynomial of the second order as a function of the depth of processing and the speed of the plow. In this case, the influence of the depth of ploughing is more pronounced. The speed of motion affects less; this effect is close to linear dependence, as noted in a similar study [11].

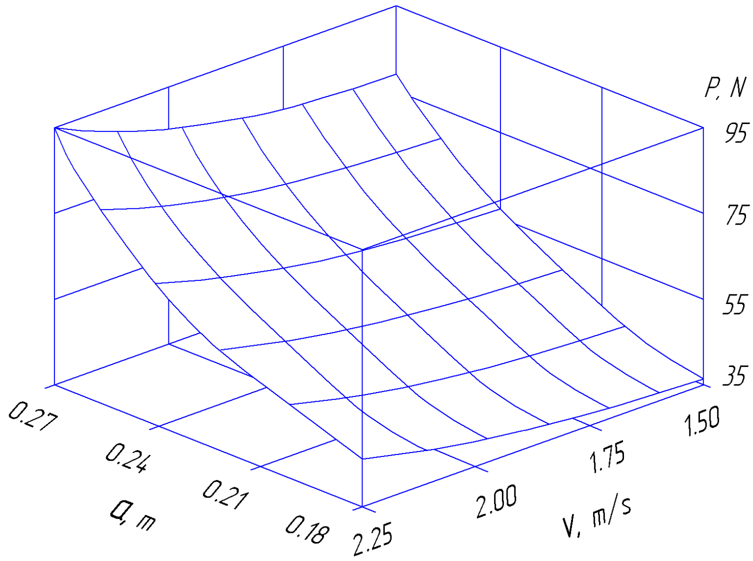

Figure 4. Graph of the dependence of the soil pressure on the shield against the depth of plowing and speed of the plow

4. Conclusion

The increase in the resistance of the plow was insignificant. If the shields are placed on a plow with four working bodies with a working width of 0.35 m, its resistance will increase by 130-330 N if the depth of plowing varies from 0.18 to 0.27 m and the speed of movement is from 1.5 to 2.25 m / s. The increase in power costs is 190-750 watts. The positive effect of increasing the angle of rotation of soil layers is also that there is no need to use coulters. Coulters require more energy than shields on the plow. This means that plowing with a device to increase the angle of rotation of soil layers requires less energy than plowing with coulters. Thus, the increase in the angle of rotation of soil layers during plowing by widening the furrow with additional shields on the plow not only improves the agrotechnical indices of the field operation, but also saves the power costs for plowing.

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