The Design of a Dump Plow for Processing Heavy Soils

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Abstract. The design of a multi-body plowshare for processing heavy soils has been developed, namely, a new working body has been developed for preliminary destruction of the soil layer before its rotation by the main body of the plowshare. According to the results of the preliminary analysis, the working bodies for the ploughshare were selected and designed for the optimal operation of this tool in almost all weather conditions.

1 Introduction

In all its diversity, general-purpose plows have not yet exhausted their potential for developing original designs and new working bodies. Despite the emergence of new technologies for tillage, dump plowing remains an urgent and important operation, as it provides high-quality soil preparation for sowing crops on a wide variety of backgrounds and soil types. Dump plows are indispensable tools capable of deeply sealing crop residues, which contributes to the destruction of weeds, small pests and diseases of agricultural crops without the use of herbicides.\cite{1}

The methods of dump plowing are continuously being improved, only the principle of operation of the plow body remains unchanged: the fall-off and turnover of the formation into an open adjacent furrow.

At the same time, ploughshares are not devoid of a number of serious technological disadvantages: high energy consumption and low productivity, compacted furrow bottom, insufficient soil crumbling, unsatisfactory cohesion and alignment of arable land.

In this regard, the purpose of our work is to improve the quality and reduce the energy intensity of basic tillage by improving the stability of the arable unit.

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2 Materials and methods

As a research method, we used the method of morphological and functional analysis. The analytical description of the technological process was performed using a digital photo and video camera. The study of methods and means of mechanization was carried out in the laboratory of the Faculty of Mechanization of the Kuban State Agrarian University and in field conditions in accordance with current standards and methods [2].

In order to determine the shape and location of the plane-cutting razor on the plow body, we analyzed the theoretical data of the operation of a flat and two-sided wedge in the soil. Using the COMPASS-3D software product, drawings of the location of a plane-cutting razor on the plow body were made and its geometric dimensions were obtained in relation to the width of the plow body.

3 Results

During plowing, energy is spent both on useful work (compression, crumbling, rotation and displacement of the formation, and on overcoming harmful resistance forces caused by friction of working bodies on the soil, adhesion of its particles, soil stickiness, etc., and harmful resistance can reach up to half of the total resistance to plowing. Attempts to reduce harmful resistances did not yield anything, except for lining the blade with plastic (reducing resistance to 20%), however, this method has not found modern application and introduction into mass production.

The purpose of tillage is to prepare it in order to create conditions for high-quality sowing, stimulate the growth and development of the root system, ensure access to nutrients and maximize moisture retention. The treatment should not destroy the optimal soil structure, but preserve soil fertility and protect the soil from erosion processes. It should not be excessively energy-consuming, but it should take as little time as possible and not be very expensive.

For the most part, the design of all tillage tools is based on the theory of a "wedge" or the interaction of soil with a two- or three-sided wedge. According to the geometric shape, the working bodies of the plow and other tillage implements are made as flat or curved wedges. Flat wedges - plough-shares, knives, cultivator paws, harrow teeth; curved - spherical discs of harrows, huskers, plough dumps, hoppers. The wedge shape is typical for the coulters of seeders and planters. A flat wedge. Under the influence of such a wedge, soil deformation occurs, the nature of which depends on the technological properties of the soil and the angle, and the installation of the working face of the wedge to the horizontal. [3]

Poorly connected soils. The main type of their deformation is shear. When the wedge is moved from position I to position II, soil particles a, b (column 1, a) are pressed into the not yet deformed mass and move to position a', b', i.e. the material is compacted. The crumpling stress at point a is greater than at point b, since aa' > bb'. As soon as the crushing stress exceeds the temporary shear resistance of the soil, a shear plane OA will appear in front of the wedge blade, directed at an angle Ψ to the bottom of the furrow, and a prismatic block OA will separate from the formation.

After chipping, the blocks slide along the surface of the flat wedge without undergoing new deformations, and therefore do not disintegrate. The size of the broken off blocks depends on the thickness of the formation (depth of processing). The thin layer breaks up into smaller lumps than the thick one [4-8].

Medium and highly cohesive (loamy and clay) soils of optimal humidity. At the very beginning of the wedge introduction, an OS crack is formed (Figure 2, b). It expands, and the EPA element breaks away from the formation. With further movement (from position I
to position II), the wedge first cuts off chips of variable thickness along the 00' line (cleans the bottom of the furrow), then forms a new crack O'C' and tears off the next element of the formation. Hard and dry soils. The fracture crack extends downwards (Figure 2, c), the bottom turns out to be uneven, and the broken off block of the formation has an irregular shape.

Heavily blackened and moist loamy soils are torn apart by a wedge along the line of movement of the blade. Cracks that occur during the bending of the formation do not reach the surface, i.e. the formation is not divided into separate elements and is a continuous ribbon (Figure 1, d).

A curved wedge. The wedge surface continuously deforms the formation (Figure 2, e), and it breaks up into small parts.

The deformation of the formation is affected by the intensity of the change (increase) of the angle α along the height of the wedge. The greater the difference between the angles α₁ and α₂, the more the formation crumbles. However, at α = 45...50° the soil stops sliding up the work surface and is unloaded in front of the wedge.

Depending on the direction of movement and the location of the blade, relative to the horizontal and vertical planes, the nature of the impact of the two-sided wedge on the soil varies.

**Figure 1.** Deformation of the soil by flat (a - f) and curved (e) wedges

A dihedral wedge with an angle α (Figure 2, a) separates the formation from the bottom of the reservoir, lifts it, compresses it in a vertical plane and splits it into separate lumps.

A dihedral wedge with a γ angle (Figure 2, b) separates the formation from the furrow wall, pulls it aside and compresses it in a horizontal plane [9-17].

The combined action of wedges with angles α and γ contributes to the destruction of the formation in two directions. Further crumbling of the chipped pieces stops when they move along the surface of the wedges, since the angles α and γ have a constant value. For intensive crumbling of the formation, a series of simple wedges with gradually increasing angles α and γ should be placed one after another, i.e. a simple flat wedge should be replaced with a curved one.

A dihedral wedge with an angle β (Figure 2, c) tilts the formation to the side. However, to transfer the formation from a horizontal position to an inclined one, not one, but many wedges located one after the other with an angle increasing from 0 to 90 ° β, and for the rotation of the formation the angle must be more than 90 °.

A triangular wedge. The sequential impact of three dihedral wedges on the formation can replace one triangular wedge, which is an AMVO tetrahedron (Figure 2, d) with three mutually perpendicular faces of the PTO, AOM and AOB. When moving the triangular wedge in the direction of the X axis, the AB edge cuts off the formation from the bottom of the furrow, the VM edge from the furrow wall, and the ABM face takes the formation aside, crumbles and wraps it. If the angles α, γ and β are continuously changed in height, then a flat triangular wedge is transformed into a curved surface. The effect of such a surface on the formation depends on its location relative to the bottom and wall of the
furrow and the intensity of change (development) of the $\alpha$, $\gamma$ and $\beta$ levels in height. If the angle $\alpha$ is strongly developed, the formation is intensively shrinking; if the angle $\gamma$ is developed, the formation shifts more to the side; if the angle $\beta$ is strongly developed, the surface wraps the formation well. Such surfaces, called "dumps", are used on plows, hoppers, furrow cutters, bed makers, bulldozers and other machines, the workflow of which is associated with the movement of soil or soils.

**Figure 2.** Interaction of two-sided (a...c) and three-sided (d) wedges with soil

The theory of tillage has not undergone any significant changes over the past 100 years, however, in our work we combined the principle of operation of both types of interaction of wedges with the soil at the same time. It is this principle that is inherent in the operation of all combined tillage tools. This makes it possible to improve the quality, productivity, and most importantly reduce the processing costs for this technological tillage operation in one pass of the arable plant [1-6].

When creating a rational tillage system with a reservoir turnover, it is necessary to have an accurate understanding of its role in the cultivation of agricultural plants.

Summarizing the results of many years of research by the Agrophysical Research Institute on soil physics, I. B. Revut, V. G. Lebedeva and A. I. Abramov wrote about the importance of the density of soil composition: "Soil density is the primary and determining factor of all soil physics. The water, thermal and air regimes in the soil are directly related to it... density is the most significant factor in its fertility [4].

The density value depends on the method of tillage. Various methods of tillage affect its structural condition, the structure of the arable layer, water-air, food and thermal regimes, thereby influencing the growth condition of plants, which affects their productivity.

One of the important agrophysical properties is its structure, the re-search of B. I. Tarasenko found that the high density of the arable horizon on rowed precursors makes it difficult to plow them, leads to significant lumpiness, which sometimes reaches 70%. The lumpy soil loses productive moisture, it is difficult to sow and embed seeds in the soil, their contact with the soil, germination decreases and as a result, the yield of winter wheat is reduced [5].

The main significant disadvantage of the plowshare is its high specific traction resistance, most of which is applied to the field boards installed on the plow body. This is exactly what became the goal of all our work: to reduce the traction resistance of the entire arable unit, to improve the quality and productivity of this technological operation.

The technical result of the developed tillage body is an increase in the degree of crumbling of the soil, due to its differentiated processing in depth by the main and additional working bodies, depending on the condition of the soil and the pre-spring, as well as a decrease in the traction resistance of the plow by reducing the pressure of the field board against the furrow wall.

The specified technical result is achieved by the fact that a plow was developed containing a frame, plow housings mounted on it, each of which consists of a rack, a ploughshare, a blade and a plane-cutting razor, characterized in that the plane-cutting razor is mounted on the rack from the side of the field sawn-off at an angle (15 - 45) to the direction of movement of the plough with the possibility of height adjustment, it is opposite to the angle of inclination of the ploughshare and has a width equal to the width of the grip of one plough body.
It is known that the degree of crumbling of the soil by almost all working bodies increases with a decrease in the depth of its processing. Therefore, in combined units, which use two or more working bodies installed on the same track, as a rule, longline tillage is used [6]. This principle is applied in the design of the proposed plow.

It is also known that in ploughs, the field board is pressed against the furrow wall with a force equal to the transverse component of soil resistance. In proportion to this force, resistance to sliding friction appears. Installing a plane-cutting razor from the side of the field sown-off at an angle of 15-45 degrees to the direction of movement of the plow opposite to the angle of inclination of the plowshare, provides a mirror image of the plowshare and causes transverse resistance in the sign opposite to the transverse component of soil resistance to the plowshare and the plow blade. This leads to a decrease in the resulting forces transverse to the direction of movement, as well as to a decrease in the forces of resistance to friction of the field board against the soil of the furrow wall.

The essence of the invention is explained in Figure 3, where Figure 1 shows a plow (top view): figure 2 shows a general view of the plow body; figure 3 shows a general view of the plow body in axonometric, Figure 4 shows a view and the position of a plane-cutting razor relative to the plow-share body plowshare.

The plow contains a frame 1, plow housings 2 mounted on it, each of which consists of a rack 3, a ploughshare 4, a blade 5 and a height-adjustable plane-cutting razor 6, which is mounted on a rack 3 from the side of the field sown-off at an angle \( \alpha = 15 - 45 \) degrees figure 4 type A to the direction of movement of the plow opposite to the angle of inclination of the plowshare and has a width equal to the width of the grip of one plough body, such an installation of a plane-cutting razor provides a mirror image of the plowshare. The installation of a plane-cutting razor at an angle \( \alpha = 15 - 45 \) degrees is due to the fact that the operation of a plane-cutting razor installed within specified limits ensures optimal parameters of soil crumbling at a given processing depth.

The plow works as follows. An additional plane-cutting razor 6, mounted on a plow in front of each housing 2, rolls out the upper layer of soil. Then, following the same trail, the plow body goes, cultivating the soil to a predetermined depth. At the same time, longline tillage increases the degree of crumbling of the soil and reduces the resistance to sliding friction of the field board against the soil of the soil wall [1-5].

Figure 3. The design of the developed ploughshare patent 2491807
4 Conclusion

As a result of our work, we propose the design of a ploughshare with additional working bodies made in the form of a plane-cutting razor installed on the side of the field sawn-off.

Using the computer modeling method allowed us to develop the design of a plowshare with an additional working body for preliminary destruction of the soil before its rotation by the plow body. As a result, we have achieved a reduction in traction and improved the quality of tillage. The flat-edged razor, which has smooth depth adjustment, ensures optimal crumbling over the entire range of adjustments.

References


16. Z. Sándor; M. Tállai; I. Kincses; Z. László; J. Kátai; I. Vágó, DRC Sustainable Future 1(1), 14-20 ) https://doi.org/10.37281/DRCSF/1.1.3