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The Results of Theoretical Studies of the Chisel Cultivator Rack Frontal Surface Shape

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ANNOTATION

The article deals with the theoretical study of the shape of the cross-section of the rack on the chisel cultivator. To avoid clogging the racks with plant residues, it is necessary to change its configuration so that it is possible to self-clean the racks from plant residues during operation. To find the optimal shape of the cross-section, the asymmetric experimental shapes of the frontal surface of the racks are studied. The conducted research shows that the condition of sliding plant residues towards the flat face of the frontal surface of the rack depends on the angle of its inclination to the direction of movement, the physical and mechanical properties of the soil and plant residues, as well as the thickness of the rack.

Keywords: working body, rack, shape of the frontal surface, plant residues, cross-section shape, rounded and flat frontal part, soil friction force.

INTRODUCTION

Clogging of the working bodies of tillage machines with plant residues reduces the reliability of the technological process and worsens the agrotechnical and energy indicators of its operation. As numerous studies show, the clogging and sticking of working bodies largely depends on the shape and parameters of the frontal surface and the cross-section of their racks./1-8/ However, to date, there are no original technical solutions that exclude clogging the racks of working bodies with plant residues. In this regard, the task was set to develop and justify the shape and parameters of the cross-section of the rack of working bodies of tillage machines, ensuring its self-cleaning from plant residues. A number of forms of cross-section of racks of

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working bodies are known/9 /

Now let's consider the condition for the removal of plant residues from the rack. This depends on the shape and cross-sectional parameters of the frontal surface of the rack. The racks of the working bodies of chisel and other tools always work in loosened soil, that is after the formation is deformed by the paw. Working in a loose environment, racks, even with a sharpened cutting edge, cannot provide cutting of plant residues due to the lack of a counter-cutting stop. Therefore, the frontal working side of the racks with a non-streamlined shape can be enveloped by powerful plant residues, contributing to the general clogging of the working bodies, especially on soils with high humidity.

Racks of working bodies with a rectangular shape of the frontal surface are not subject to enveloping with plant residues when working mainly on dry soils and in fields with a low content of high-stemmed plant residues. When working on wet soils, the sliding of plant residues from the racks is sharply reduced due to their breaking at the sharp corners of the frontal surface, as a result, the working bodies are periodically clogged.

The most intense sliding of plant residues of all types occurs when working with racks with a semicircular and oval shape of the frontal surface. However, with an increase in the speed or humidity of the soil, clogging with plant residues occurs.

MATERIALS AND METHODS

The force of pressing the plant with the soil to the frontal surface of the rack in all known forms of cross-section, except for the asymmetric one, is the same on both sides of the top of the cross-section. This prevents the plant residues from sliding to the side and coming off the rack, which leads to the latter being enveloped in plant residues. For a rack with an asymmetric wedge-shaped cross-section, due to the displacement of the cutting edge from the middle of the rack thickness and the difference in the angles of sharpening of the edges, the forces acting on the stem, enveloping the rack, have different magnitudes on opposite edges, and a larger width of one of the edges and a smaller angle of its inclination ensure the sliding of the stems along this edge and, ultimately, self-cleaning of the stand from plant debris. However, in this cross-sectional shape, when it meets the sharp cutting edge of the rack, the plant residues break and, as a result, the slip of plant residues along its edges is hampered, and therefore, their descent worsens.

RESULT AND DISSCUSION

Taking into account the noted disadvantages of the existing forms of the cross-section of the racks, at the level of the invention / 10,11 / we have developed options for the rack of the working bodies of the chisel cultivator with an asymmetric frontal surface having a rounded top and

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various forms of side faces (Fig. 1).

Option 1. Rack 1 of the working body (Fig. 1, a) has the main bearing body 2 and the frontal surface 3, which has an asymmetric shape in cross section. The frontal surface 3 has a flat face 4, which is smoothly conjugated with the opposite lateral face 5 of the rack with an arc 6 of radius rm and with the adjacent side 7 and arc 8. The lateral faces 5 and 7 of the rack are made flat.

Option 2. Rack 1 of the working body (Fig. 1, b) also has a supporting body 2, asymmetric, consisting of small 4 and large 5 side faces, frontal surface 3, concave side face 6 and convex side face 7 of the rack. The side faces 4 and 5 of the frontal surface 3 are convex and of different sizes. Face 4 has a greater curvature, and face 5 has a lesser curvature. The lateral face 5 of the frontal surface is smoothly conjugated with the smaller face 4 and the lateral face 7. The lateral face 6 of the pillar is made concave to the equidistant face 5 at a distance of double the radius of curvature of face 4.

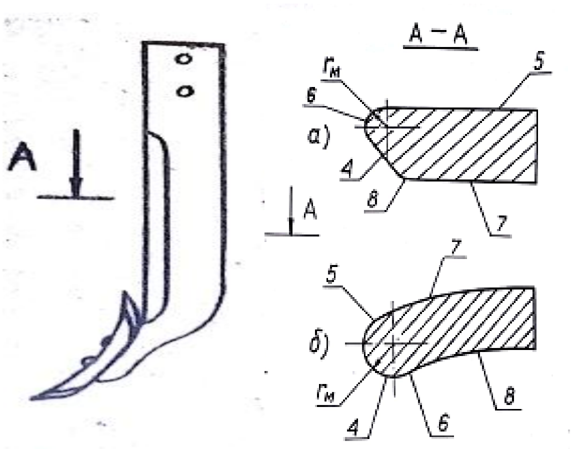

Fig. 1. An asymmetric experimental rack with a rounded top of the frontal surface: a) option 1 - with flat side faces;
b) option 2 - with convex-concave side faces,

Let us consider the condition for the descent of weeds from the frontal surface of the developed racks during the translational movement of the working body, plant residues collide with the front rounded top of the frontal surface of the rack, bend around it and begin to move with it in the direction of movement (Fig. 2.4), while the force of the frontal resistance of the soil gives the component directed along the flat (large) face in the direction opposite to the direction

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of movement.

This force tends to move plant residues along the frontal surface of the rack. However, this is prevented by the friction force arising from the interaction of the rack with the soil and plant residues. To ensure their descent from the stand, the force that causes the plant residues to slide along its flat edge must be greater than the force that prevents them from sliding, i.e.

$$P_c \geq P_{п} \qquad (1)$$

Where, Pc is the force promoting the sliding of plant residues along the frontal surface of the rack to the side;

Rп - the force that prevents the descent of the frontal surface.

From Fig. 2. we have

$$P_c = N_T = \text{N ctg } \beta_1, \qquad (2)$$

We determine the normal force acting on the plant residue from the side of the flat face of the frontal surface of the rack. To do this, we assume that the specific pressure arising on the cross-section of the rack from the resistance of the soil is evenly distributed along its entire perimeter.

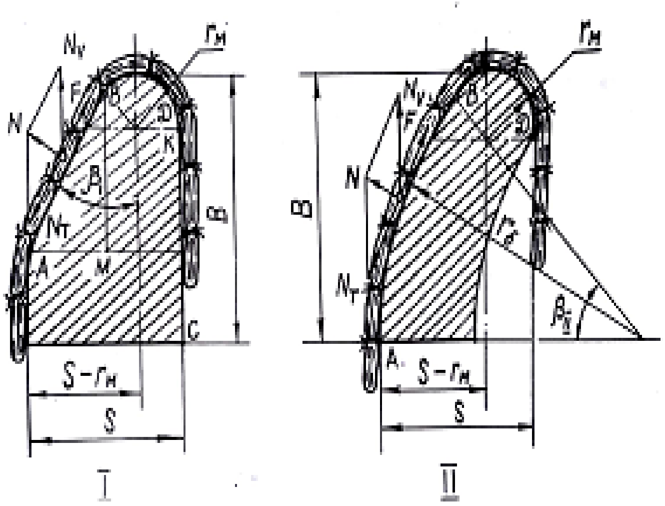

Fig. 2. Scheme of interaction with plant residues of an asymmetric stand with a rounded apex of the frontal surface: **I -** with flat lateral edges; **II** - with convex-concave lateral faces, where **N** is the normal force acting on the soil and plant residue from the side of the flat face of the frontal surface of the rack; $\boldsymbol{\beta_1}$,- the angle of inclination of the flat face of the frontal surface of the rack

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to the direction of movement.

Then, according to Fig. 2

$$N = q \cdot l \cdot t, \tag{3}$$

where **q** is the specific soil pressure on the frontal surface of the rack;

l - the length of the flat edge of the rack;

t- is the thickness of the weed stem.

Let us express ***l*** in terms of **S**, $\mathbf{r_M}$, and. of Δ ABM

$$l = AB = \frac{MA}{\cos(90^0 - \beta_1)} = \frac{MA}{\sin\beta_1}, \tag{4}$$

Since

$$MA = S - r_M - r_M cos\beta_1 - S - r_M(1 - cos\beta_1), \tag{5}$$

$$l = \frac{S - r_M(1 - cos\beta_1)}{sin\beta_1}, \tag{6}$$

Taking into account (3) and (6), expression (2) has the following form

$$P_c = q\, \frac{S - r_M(1 + cos\beta_1)}{sin\beta_1} t \cdot ctg\beta_1, \tag{7}$$

where S is the width of the cross-section of the rack.

The friction forces arising in the sections AB, BK and KC prevent the descent of the crop residue from the stand, i.e.

$$P_п = F_{AB} + F_{BK} + F_{KC}, \tag{8}$$

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We determine the friction force arising along the flat face of the frontal surface of the rack:

$$F_{AB} = f \cdot N = f \cdot q \cdot l \cdot t, \qquad (9)$$

where f is the coefficient of friction of plant residues on the rack material.

Taking into account (6), the expression (9) has the following form

$$F_{AB} = f \cdot q \, \frac{S - r_M(1+cos\beta_1)}{sin\beta_1} t, \qquad (10)$$

Next, we determine the friction force that occurs along the arc

$$F_{BK} = f \cdot q \cdot r_M \cdot t(\pi - \beta_1) \qquad (11)$$

According to the research of A. N. Zelenin. / 12 / the friction force that occurs on the side surface of the rack is insignificant compared to the friction force that occurs on its frontal surface. Therefore, we will not take it into account in the calculations.

Taking into account (10) and (11), the force preventing the plant residues from sliding towards the flat face of the frontal surface of the rack is equal to

$$P_п = f \cdot q \cdot r_M \cdot t\left[(\pi - \beta_1) - \frac{1+cos\beta_1}{sin\beta_1}\right] + f \cdot q \, \frac{S}{sin\beta_1} \cdot t, \qquad (12)$$

Substituting the value of Pc and Pп in (1), we obtain

$$q \, \frac{S - r_M(1+cos\beta_1)}{sin\beta_1} \cdot t \cdot ctg\beta_1 \geq f \cdot q \cdot r_M \cdot t\left[(\pi - \beta_1) - \frac{1+cos\beta_1}{sin\beta_1}\right] + f \cdot q \, \frac{S}{sin\beta_1} \cdot t, \qquad (13)$$

Or

$$\frac{S - r_M(1+cos\beta_1)}{sin\,\beta_1} ctg\beta_1 \geq f \cdot r_M\left[(\pi - \beta_1) - \frac{1+cos\beta_1}{sin\,\beta_1}\right] + f \frac{S}{sin\,\beta_1}, \qquad (14)$$

Whence, after some transformations and taking into account that $f = tg\varphi$, we get

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$$r_M \leq \frac{S(ctg\beta_1 - tg\varphi)}{(\pi-\beta_1)tg\varphi sin\,\beta_1 + (1+cos\beta_1)(ctg\beta_1 - tg\varphi)}, \quad (15)$$

Thus, the condition of sliding plant residues towards the flat face of the frontal surface of the rack depends on the angle of its inclination to the direction of movement, the physical and mechanical properties of the soil and plant residues, as well as the thickness of the rack.

As can be seen from the analysis (15), a mandatory condition for the sliding of plant residues along the flat face of the rack is

$$ctg\beta_1 > tg\varphi \quad (16)$$

Or

$$ctg\beta_1 < 90^0 - \varphi \quad (17)$$

Similarly, for the second variant of the experimental rack, we obtain

$$r_M \leq \frac{B\left(\frac{\pi}{2}-\varphi\right)\left(ctg\frac{\pi-2\varphi}{4} - tg\varphi\right)}{\left(\frac{\pi}{2}+\varphi\right)sin\varphi + \left(\frac{\pi}{2}-\varphi\right)\left(ctg\frac{\pi-2\varphi}{4} - tg\varphi\right)(1-cos\varphi)}, \quad (18)$$

$$r_б > \frac{B}{cos\varphi}\left[1 - \frac{\left(\frac{\pi}{2}-\varphi\right)\left(ctg\frac{\pi-2\varphi}{4} - tg\varphi\right)}{\left(\frac{\pi}{2}+\varphi\right)sin\varphi + \left(\frac{\pi}{2}-\varphi\right)\left(ctg\frac{\pi-2\varphi}{4} - tg\varphi\right)}\right], \quad (19)$$

Where

$r_M, r_б$ are the radiuses of curvature of the small and large faces of the frontal surface of the rack; **B** - is the length of the cross-section of the rack.

Calculations carried out according to formulas (15), (18) and (19) β_1=30°, φ=45° S=30 mm and B=60 mm show that to ensure the descent of plant residues and rhizomes from the rack, the radius value r_M for the first version of the rack should be no more than 9.1

mm, for the second – 32.6 mm, and the radius value- $r_б$ not less than 51.5 mm.

Conclusions

1. To ensure the sliding of plant residues on the frontal surface of the rack, the radius of its curvature must be at least 28 cm.

2. Taking into account the noted shortcomings of the existing forms of the cross-section of the racks, we have developed options for the rack of the working bodies of the chisel cultivator with an asymmetric frontal surface having a rounded top and various forms of side edges.

3. The condition of sliding of plant residues towards the flat face of the frontal surface of the rack depends on the angle of its inclination to the direction of movement, the physical and mechanical properties of the soil and plant residues, as well as the thickness of the rack.

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