



## INSTALLATION OF PASSIVE WORKING TOOLS WITH LANCET FOOT IN ONE ROW WITH OVERLAPPING

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Modern tillers are equipped with passive working tools with ripper tines in the front rows and lancet tines in the rear rows. Despite all the improvements made in the last few decades, passive working tools with lancet tines have one common disadvantage - they cannot be mounted on the frame of the implements in one row with overlapping. Meanwhile, single-row arrangement of passive working tools with lancet tines is essential in providing compactness and maneuverability of tillers, reducing their overall dimensions and reach length, the way of working tools burial and embedding and, ultimately, reducing the size of rotary strips. To eliminate drawbacks of serial passive working tools, we have developed a passive working tool with a lancet foot, consisting of a rack, bit and two asymmetric wings. The bit is rigidly fixed to the jig, while asymmetric wings with different solution angles are hinged by the elastic element to the rack. This working device, in spite of their installation in one row with overlapping, has slits between the wings of adjacent duckfoot formed due to the difference of solution angles of asymmetric wings in the movement direction, so the plant remains are free to come off the wings and pass through these slits, preventing thereby the unloading of the soil. The hinge and the elastic element provide free deflection of the asymmetric wings of the arrow wings in the longitudinal-vertical plane relative to the stand, but at the same time it prevents its deflection in the horizontal plane, hence the formation of an untreated strip between adjacent tines.

**Key words:** tillage machine, passive working bodies, duckfoot share, soil, burial path, chisel, wings, elastic element

### 1. Introduction

Review of the state of affairs on soil preparation for sowing crops in the country has shown that regardless of the type of technology of pre-sowing tillage and the variety of machines and implements used for its implementation [1-4] in all cases the following is observed: deep loosening of the soil (to a depth of 14-20 cm) is carried out by passive working tools; shallow cloddy surface tillage (to a depth of 8-10 cm) is carried out by teeth, discs or rotor, and for leveling and compacting the soil surface, leveling and compacting working tools of various designs are used and the quality of soil preparation for sowing mainly depends on their work efficiency.

Among these operations, deep loosening the soil with passive working tools creates a favorable zone for growth and development of the root system of the cultivated plant [5] Therefore, in all cases, in preparing the soil for sowing, soil loosening, in which deep loosening the soil with passive working tools, equipped with rippers and flail tines, takes place [6].



Ripping tines of passive working tools have undergone several improvements in the last decade. Their designs have changed from simple chisels [7] and then reversible chisels [8] to mouldboard chisels [9] and wing-shaped chisels [10]. The designs of slotted legs also underwent changes: lancet, universal, flat-blade, one-sided and other forms were developed [11-13].

Modern chisel tillers are equipped with passive working tools, equipped with ripper tines on the front rows and lancet tines on the rear rows. However, despite all improvements, passive working tools with lancet tines have one common disadvantage - they cannot be mounted on the frame of the implements in one row with overlapping. Meanwhile, single-row arrangement of passive working tools with wing shares is essential in providing compactness and maneuverability of machine guns, reducing their overall dimensions and reach length, the way of working tool burial and embedding and, in the end, reducing the size of rotary strips. In addition, standard passive working tools with a lancet foot compact the lower layers of soil with their bearing surface.

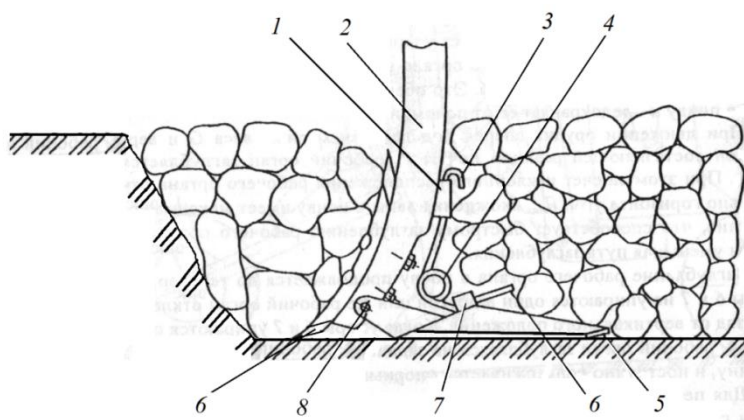
**2. Materials and methods**

Studies have established [14] that the smaller the area of the bearing surface of the blade, the less resistance to penetration into the soil, therefore, the length of the path of penetration of the tool into the soil.

With the conventional passive implement design, the bearing surface of the blades can be reduced by reducing the working width of the tine. However, this is associated with a number of difficulties, in particular to ensure a constant working width of the tillage machine it is necessary to increase the number of passive working tools, and this will lead on the one hand to an increase in traction resistance, and on the other hand - to carry out the lower wet layers on the day surface of the field by the stand.

In recent years, a number of original technical solutions have been developed to eliminate the noted disadvantages of traditional passive working tools.

One of such technical solutions [15], which solves a similar problem, is a passive working device (Fig. 1), containing stand 2, shooting foot, consisting of bit 6 and hinged wings 5 (A.s. SU1817953). The chisel is rigidly mounted on the stand, while the wings of the shooting foot are hinged by means of the hinge 8 and are additionally connected to the stand by the elastic element 4.



**Figure 1.** Passive working body with articulated wings

The elastic element can be made of a torsion spring as in Fig. 1 or a tension-compression spring as in figure 2 or another similar elastic-elastic material.



The elastic element by means of brackets 1, 7 is loosely connected with one end 3 to the rear side of the post, and the other end 6 to the middle part of the adjacent wings of the duckfoot.

During the work of the tool the chisel loosens and the wings of the duckfoot undercut the soil layers to a specified depth and crumble it without turning the layer. The hinge and the elastic element provide free deflection of the winglets of the winglets in the longitudinal-vertical plane relative to the stand, but at the same time it prevents its deflection in the horizontal plane, therefore, the formation of an untreated strip between adjacent tines. In addition, they enable the duckfoot wings to work as a weather vane.

After the implement has been lifted out of the ground, the elastic element returns the wings of the wing shares to their original position. This prevents it from sagging and breaking during lowering from transport to working position during subsequent implement operating cycles.

Despite the obvious advantage over the traditional and these passive working tools are not without drawbacks, in particular, in some cases, the complexity of the machine design, and in others - a high probability of failure of elastic elements when transferring the machine from the transport to the working position. However, a common positive feature of these technical solutions is that at the initial stage of burial in the soil, due to the change in spatial position of the passive working tool or its individual structural elements, the supporting surface of blades of the tine decreases significantly. Consequently, the reaction force of the lower soil layers decreases, as a result of which the path of working tool penetration into the soil is significantly reduced. In addition, the free deflection of the wing blades in the longitudinal-vertical plane also reduces the penetration of the tool out of the ground. In spite of these clear advantages over the known passive working tools, this tool does not provide the same overlapping installation.

### 3. Research results and discussion

To eliminate the disadvantages of passive working organ with articulated wings, the most suitable is a passive working organ with asymmetric foot (A.s. SU 1727569), adopted as a basic model for further development [16].

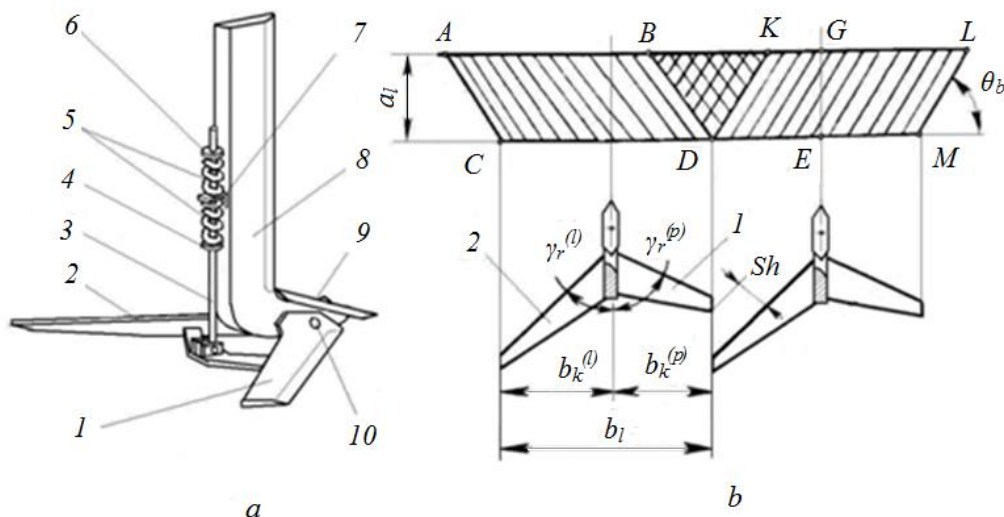
This working body (Fig. 2) has a stand 8, a chisel 9 and asymmetrical right 1 and left 2 wings. Wings of the tine can be made in a rigidly fixed (see Fig. 3) or articulated (see Fig. 2) version to the stand [17]. In case of hinged attachment, the asymmetric leg wings are hinged to the post by means of the lead system 3 and the hinge 10, and their angular oscillations are damped by stabilizing springs 5 (further stabilizer) put on the lead and resting with one end in the lead bracket 7, and with other ends in stop rings 4, 6 fixed on the lead. In both variants, the right (P) and left (L) wing of the paw are made with different angles of solution  $\gamma_r^{(p)}$ ,  $\gamma_r^{(l)}$  and width of gripping  $b_k^{(p)}$ ,  $b_k^{(l)}$ .

The working principle of the asymmetric tine is slightly different from that of the symmetric arrow tines. With asymmetric tines in the cross-vertical plane (Fig. 2, b) the soil to the left of the KD line is deformed by the right wing of the adjacent tine. Therefore, their left wing produces displacement of soil over the area equal to the area of trapezoid KGED when the plane comes to the surface of undisturbed soil and the area of triangle VCD when it comes to the disturbed zone to the left of the KD line. Consequently, the right wing performs soil displacement with the ledge closed from both sides, i.e., it works in a blocked environment.



Whereas the left wing works with the ledge open on one side, i.e., in the soil medium unblocked on one side. In this case the wing with big solution angle breaks and loosens the soil to the depth  $a_l$ , and the wing with smaller solution angle undercuts the soil partially broken by the wing (with big solution angle) of the adjacent working tool.

With these tools, despite their installation in one row with overlapping, due to the presence in the direction of movement of the slot "Sh" between the wings of adjacent tines, plant residues freely come off the wing blades and pass through these slots, thereby preventing the piling up of the soil.



**Figure 2.** Passive tool with asymmetric tine (a) and scheme (b) of soil deformation by it

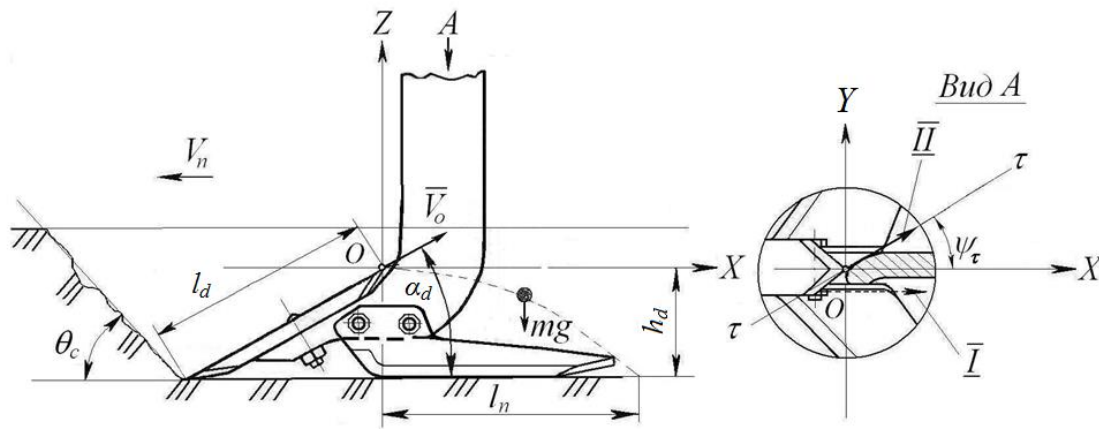
To ensure self-cleaning from plant residues and to reduce energy consumption, the prop 8 of this passive working device is also made with differently-sized side faces (A.s. SU 1704650) [18]. Its large edge "B" relative to the asymmetric leg is located on the side of its wing with a shorter length.

In this working body, in order to create favorable conditions for unblocked loosening of the soil with the chisel, a shear zone not filled with soil with the least resistance of the soil deformed by the wing with a smaller angle of the adjacent tine solution should be created.

Therefore, when justifying the chisel parameters, not only the soil loosening conditions must be taken into account, but also the creation of an unfilled soil zone for moving the soil shifted by the wing with a smaller angle of the adjacent tine solution.

When the chisel operates, the soil layer in front of the chisel first compacts to a certain limit, and then it shifts at an angle  $\theta_b$  to the horizon (Fig. 3). Then, the soil particles, coming off the chisel surface, make a trajectory, forming a temporarily unfilled soil zone between the bottom of the chisel and the trajectory. Consequently, thereby creating the necessary conditions for the work of the wing with a smaller angle of the adjacent tine solution.





**Figure 3.** Scheme for determining the trajectory of soil particles coming off the chisel surface

Using the following assumptions, we determine the trajectory of the soil particles:

- when describing the equation of motion of soil particles, we assume that the chisel stands and the soil particle moves up the chisel with velocity  $V_o$  and after the descent it makes a trajectory of free flight;
- due to insignificance we neglect the air resistance;
- The trajectory of the soil particles motion is determined for the worst case, i.e. for the case when the soil particles move not parallel ( $I$ ) to the axis  $X$ , but at an angle ( $II$ ), in the direction of the tangent " $\tau - \tau$ " drawn from the top toe of the bit to the surface of the stand, which has a differently sized working surface. In this case, the length of the unfilled zone created will be the shortest.

Taking into account the fact that due to the deformation of the soil in interaction with the bit there is some decrease in the speed of movement of soil particles along the bit, we get

$$V_o = V_n(1 - K_v), \tag{1}$$

where  $V_n$  is translational velocity, m/s;

$K_v$  - the coefficient that takes into account the loss of velocity due to soil deformation.

Then let us make differential equations of motion for the  $i$ -th soil particle with mass  $m_i$  coming down from the chisel surface;

$$m_i \frac{dV_{ox}}{dt} = 0, \tag{2}$$

$$m_i \frac{dV_{oy}}{dt} = 0, \tag{3}$$

$$m_i \frac{dV_{oz}}{dt} = -m_i g, \tag{4}$$

where  $t$  is the current time value, s;

$g$  - acceleration of free fall, m/s<sup>2</sup>.

By integrating equations (2), (3) and (4) twice and defining constants of equations (1), (2) and (3) we write them in the following form:



$$x = V_o t \cos \alpha_\delta \cos \psi_\tau, \tag{5}$$

$$y = V_o t \cos \alpha_\delta \sin \psi_\tau \tag{6}$$

$$z = V_o t \sin \alpha_\delta - \frac{1}{2} g t^2. \tag{7}$$

Substituting  $t = \frac{x}{V_o \cos \alpha_\delta \cos \psi_\tau}$  in equations (6) and (7), we obtain the equations of motion of the soil particle after it comes off the bit

$$y = x t g \psi_\tau, \tag{8}$$

$$z = x t g \alpha_\delta \frac{1}{\cos \psi_\tau} - \frac{g x^2}{2 V_o^2 \cos^2 \alpha_\delta \cos^2 \psi_\tau}. \tag{9}$$

When a soil particle falls to the bottom of tillage  $z = -h_\delta$ , and  $y = l_n t g \psi_\tau$ . Then equation (9) will take form

$$-\frac{g x^2}{2 V_o^2 \cos^2 \alpha_\delta \cos^2 \psi_\tau} + x t g \alpha_\delta \frac{1}{\cos \psi_\tau} + h_\delta = 0. \tag{10}$$

According to equation (1), expressing  $V_o$  through  $V_n$  and solving equation (10), we find the maximum length of the unfilled zone  $l_n$ , i.e.

$$l_n = \left[ V_n (1 - K_v) \sin \alpha_\delta + \sqrt{\left( V_n (1 - K_v) \sin \alpha_\delta \right)^2 + 2 g h_\delta} \right] \frac{V_n (1 - K_v)}{g} \cos \alpha_\delta \cos \psi_\tau. \tag{11}$$

From equation (11) we can see that the length of unfilled zone at a given forward speed  $V_n$  depends mainly on the following parameters of the passive tool: penetration angle and height  $h_d$  of the bit. If we take into account that  $h_d$  is nothing else than

$$h_d = l_d \sin \alpha_d, \tag{12}$$

then by substituting (12) into (11) at a given angle of approach  $\alpha_d$ , varying the values of bit length  $l_d$ , we can create the necessary length of the unfilled zone.

Usually for a flat bit  $\alpha_d = 35 - 40^\circ$  [16], we accept  $\alpha_d = 38^\circ$ . Then, at  $V_n = 1.7 \text{ m/s}$ ;  $K_v = 0.2$  and  $\psi_\tau = 40^\circ$  according to equation (4.24) to provide in terms of necessary for unblocked loosening of soil by wing with smaller angle of adjacent blade solution length of unfilled soil zone the bit length should be  $l_d = 191 - 227$  mm. Let's take  $l_d = 210$  mm, that corresponds to chisels parameters of working tools produced by the leading foreign companies and CIS machines producers. For example, bit lengths are 135; 210; 232; 255 and 260 mm, which are produced by one of the world's producers of tillage implements - BELLOTA (Spain) [7], depending upon the application.

#### 4. Conclusions

Among the many designs of passive working tools, the most original, in terms of their use on cheesel tillers, is a passive working tool with a lancet foot consisting of a rigidly mounted on



the bit stand and asymmetric wings hinged to this stand. Compared with passive working tools traditionally used in the cotton-growing area, it has the following advantages:

- The asymmetrical arrangement of the tine wings allows the passive tools to be mounted in one row with overlap across the working width of the cheesel tiller.
- with full overlap in the working width, the asymmetrical arrangement of the wings allows free removal of crop residues and clods of soil from the wing blades of the tines and the passage between adjacent tines, thereby preventing soil piling up;
- The combination of the bit and asymmetric wings of the duckfoot in one working body, as well as the possibility of angular oscillation of these wings in the vertical plane reduces compaction of the soil substrate;
- articulated mounting of asymmetric wings of the duckfoot reduces the path of the passive tool, prevents the lower, wetter layer of soil to the day surface of the field;
- the compact design of the cheesel cultivator as a whole.

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