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DEVELOPMENT OF A DEVICE CONSTRUCTION THAT PROTECTS GARDEN SOIL LOCATED ON A SLOPE FROM WATER EROSION

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Abstract. This article presents the technological process of device that protects the garden soil located on slopes from water erosion. It analyzes the kinematics of the sheared soil being pulled out of the ditch to open a ditch and always create a garden-bed on the downhill side of the slope.

Key words: Slope, erosion, ditch, seedbed, sheared soil, plow, ditch opener, spherical disk, softener, hydraulic cylinder, tractor, support wheel, blade, returner, garden-bed.

Introduction: When water erosion occurs in garden soils located on sloping fields, it washes away the fertile soil layer and the soil covering the root part of the fruit tree trunk. As a result of this, the root part of the fruit tree is opened and premature drying is observed. Water usually flows downslope. In order to reduce the force of this current, a ditch is opened perpendicular to it.

After cutting the sheared soil from the ditch, which is opened horizontally in relation to the slope, with a plowshare and a knife, the movement on the base surface is continued. Since the base is set on a slope consisting of the sum of the angles $\alpha_н$ and τ_1 relative to the horizontal on the transverse vertical plane, the moving sheared soil in it rests on the blade from the side. The width of the blade corresponds to the end of the length of the base, that is, to the field surface. From this point on, the process of overturning begins on the basic working surface of the blade.

The flipping kinematics of the sheared soil is performed to ensure that it does not fall back into the opened ditch. It also serves to justify the change of the installation angle $\alpha_н + \tau$ of the referrers of the device base in the transverse vertical ZOY plane relative to the horizontal.

The ABC sheared soil, which is initially planned to be turned over, is raised in a transverse vertical plane at a distance equal to the depth a of processing and takes the position $A'B'C'$ (Fig. 1) [1,2,6,7,8].

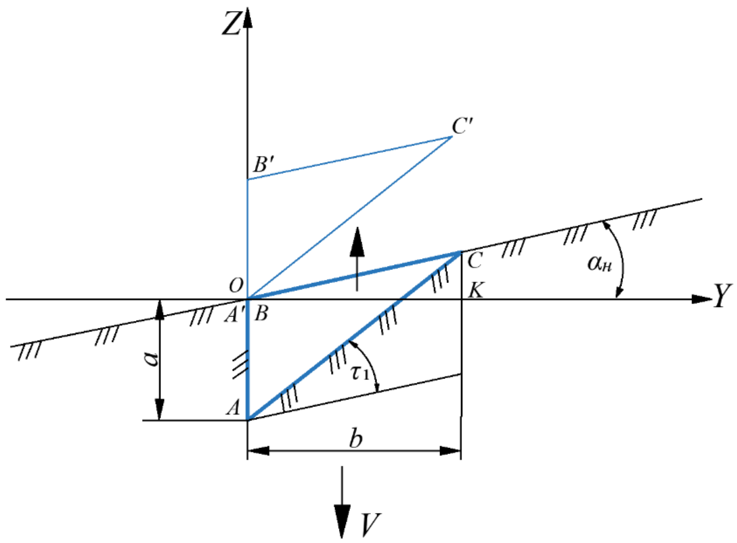

Figure 1. The scheme of the state of *ABC* sheared soil released on the field surface

This process is carried out by installing the base of the device in a longitudinal vertical plane at an angle $\alpha_к$ relative to the horizontal, that is, the base enters the soil.

At the maximum value of the angle of entry, the duration of the *ABC* sheared soil to the surface of the field and the reduction of the corresponding distance accelerates (Fig. 2)

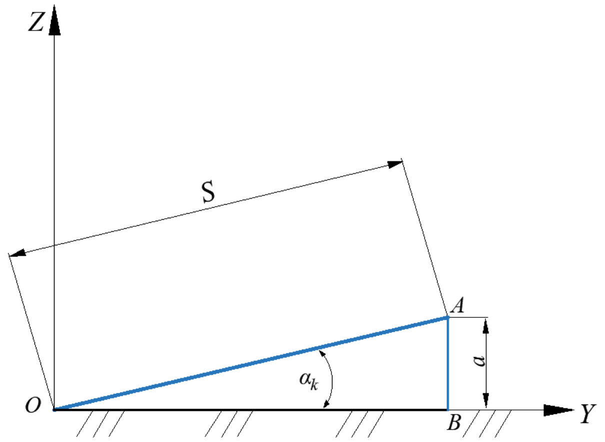

Figure 2. A scheme for justifying the rate of emergence of the sheared soil to the field surface

As can be seen from Figure 2 Δ*ABC*, at the minimum value of the angle α, the distance *S* reaches its maximum result, i.e.

$$S = \mathrm{OA} = \frac{a}{sin\alpha_к} \qquad (1)$$

here, *a* – the processing depth, m;

$\alpha_к$ – angle of entry of the device base into the soil, degree.

Expression (1) is equal to $S = 30$ см when calculated by a=15 cm and $\alpha = 30°$ values. The maximum result has two disadvantages:

– first, the longitudinal length of the device increases;

– the second one increases the length of the blade that cuts the sheared soil at the specified depth.

Both cases lead to an increase in the friction force and the metal volume of the device. However, the length of the blade *S* is continued until the *ABC* sheared soil is completely cut and brought to the field surface (Fig. 2). Because it is not possible to overturn the sheared soil without bringing it completely to the field surface [3,4,6,7,8].

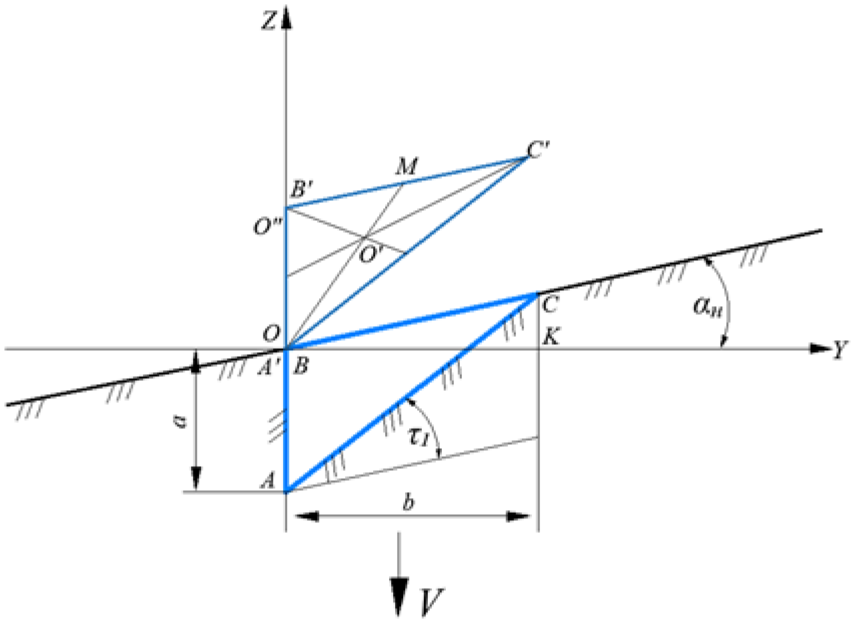

Figure 3. Scheme of the beginning of the formation process of garden-bed

The lifting of the *ABC* sheared soil to the *A'B'C'* position occurs at the beginning of the base of the device. In this section, the angle τ_1 of installation of the base working surface referrers relative to the slope will be constant. During this lifting process, *AC* side of *ABC* sheared soil is in friction with the base from bottom, and *AB* side is in friction with the working surfaces of the blade (Fig. 3).

After the *ABC* sheared soil is moved to *A'B'C'* position, the process of turning it counterclockwise around the *A'* base point, i.e., the process of garden-bed formation, begins (Fig. 3).

The process of overturning the sheared soil can be done by finding its gravity center. Therefore, initially, the gravity center *O'* of the A'B'C' sheared soil is determined (Fig. 3).

Then the *A'O'* line on the *A'B'C'* sheared soil is rotated until it becomes vertical *A'O''* position (Fig. 4) [5,6,7,8].

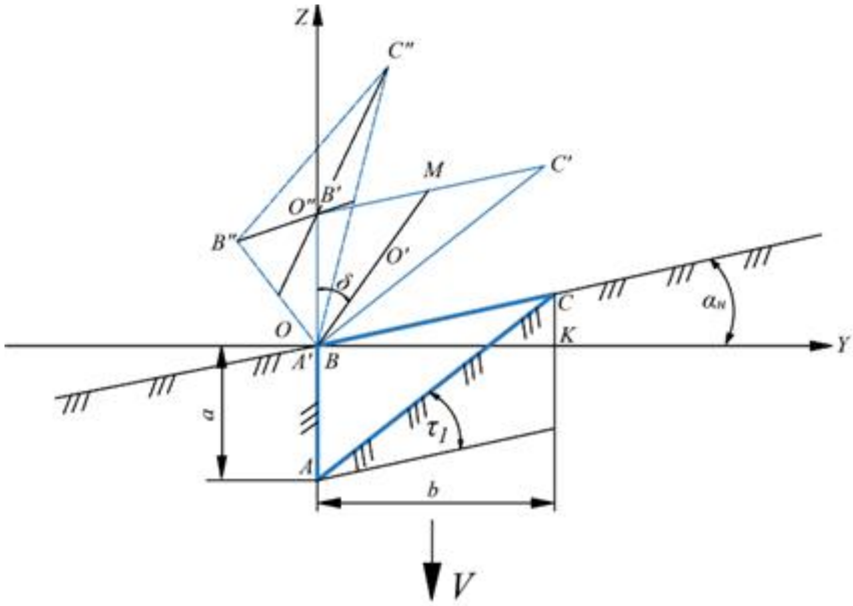

Figure 4. Unstable state diagram of the sheared soil

As a result, the *A'B"C"* sheared soil becomes unstable (Fig. 4). In this case, the *A'B"C"* sheared soil should turn over to the slope side and form a garden-bed. However, it can also fall back to its previous place, i.e. into the ditch.

The $\tau_{кр}$ angle of inclination of the base referrer corresponding to this situation was considered critical.

So, the following condition must be met in order for *A'B"C"* sheared soil to turn over and form a garden-bed,

$$\delta_i > \tau_{кр} \quad (2)$$

the angular values δ_i=38° to be rotated after τ_1 of δ_i sheared soil in the expression (2), degree.

According to Fig. 5, it is necessary to turn $A'O'$ by at least 38°. Then the $\delta_i > 38°$ condition is fulfilled, more precisely, it is equal to $\alpha_н + \tau_1 + \delta_i$=10º +30º +38º =78º

The value of the δ_i angle, which ensures the simplification in drawing base referrers and the stable state of overturning of the sheared soil, was rounded off and the result δ_i=40º was accepted. Increasing this δ_i angle up to δ_1=10°, δ_2=20°, δ_3=30°, δ_4=40° and δ_5=50° ensures complete overturning of the sheared soil (Figure 5) [6,7,8,9].

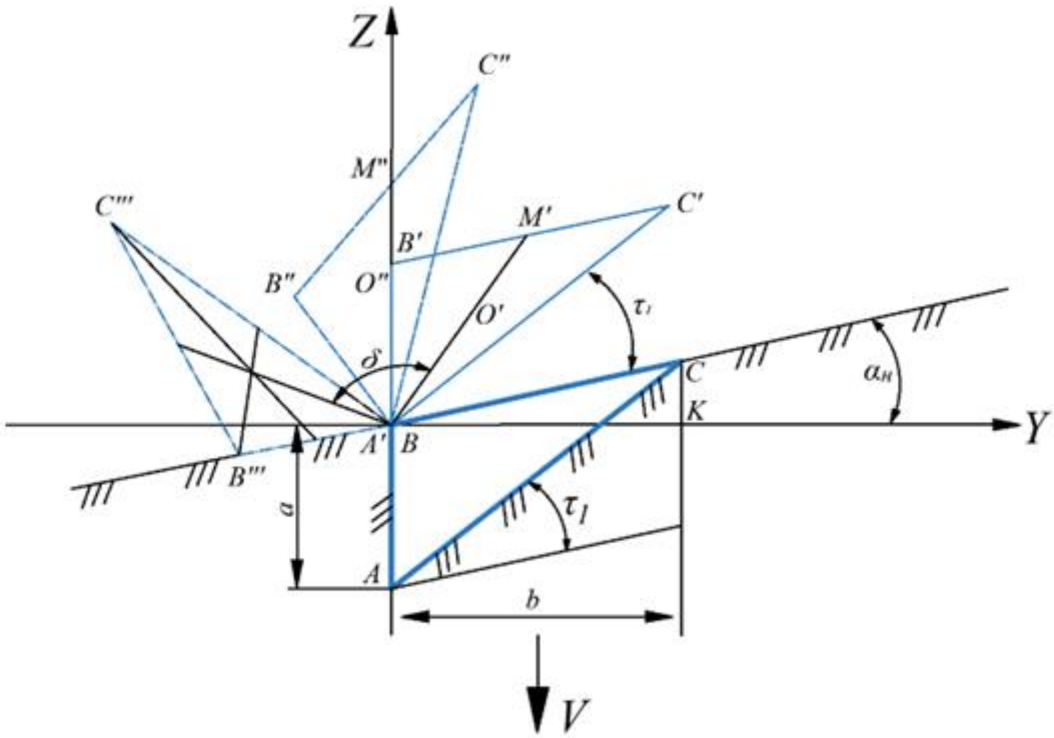

Figure 5. The scheme of justification of the complete overturning of sheared soil

For example, when δ_5=50° is equal to $\alpha_н + \tau_1 + \delta_2$ =90°, the working width *b* of the device is zero. This means that at the end of the base it will not have a working width. However, at this time, there will be no sheared soil on the working surface of the base.

Implementation of the technological process shows that the working part consists of four components. They are the base, plowshare, side blade and returners, and the next three are welded to the base.

The analysis and calculations presented above show that the quality of the technological process depends on the type of the base working surface. Therefore, in order to build the basis of the device, its scheme was presented (Fig. 6). According to it, in accordance with the *XYZ* coordinate system, the abscissa *OX*, ordinate *OY* and applicate *OZ* axes placed at an angle of 120° to each other were drawn. The working width *b (OA)* of the device is determined in the plane *ZOY*. In the *ZOX* plane, the angle of the device entry into the soil is drawn. Then a two-sided stumble in the form of *OACDЛP* is formed (Fig. 6).

We set the share along the line *OB* at an angle $\alpha_н + \tau_1$ relative to the horizontal from the point of coordinate origin O. Because the sheared soil is first cut to the horizontal at an angle $\alpha_н$, then τ_1 along the line *OB* (the angle of inclination is not shown in Fig. 6). Now the *OBEЛO* working surface is created.

In the starting part of the working surface, we determine the $S = OM$ distance according to the expression (1).

The *OЛ* side of the base is oriented at the $\alpha_к$ angle of entry into the soil.

According to the sheared soil overturning process (see Figure 4), the overturning stability was analyzed if the working surface was rotated at least 38° after surfacing [6,7,8,9,10].

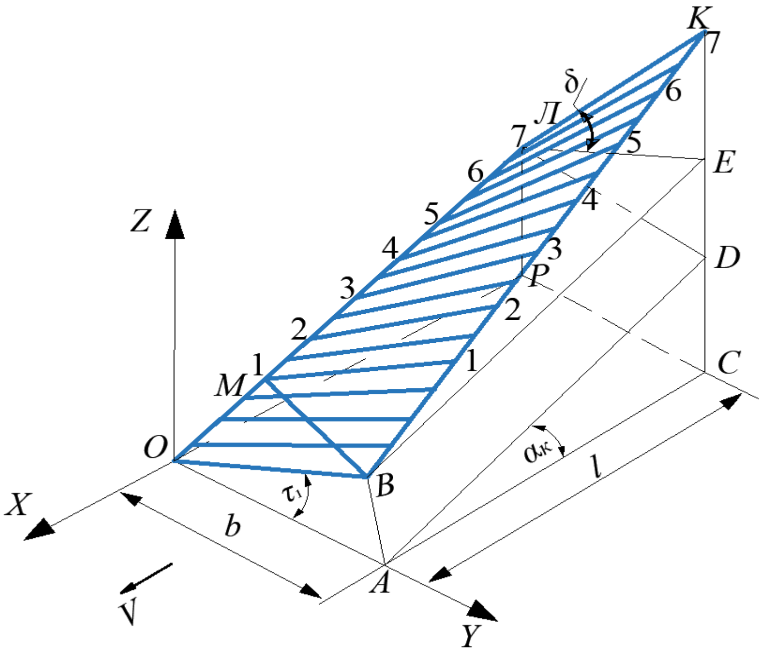

Figure 6. The scheme of the working surface of the device base

At the next stage of constructing the working surface, we increase *ЛE* to the angle δ_4=40°. For this, we draw a line *ЛK* at an angle of 40° to the line *EЛ*. The resulting *OBKЛ* surface is a new surface where the sheared soil moves and flips to the right.

We move the referrer *OB* along the lines *OЛ* and *BK* to show the working *OBKЛ* surface more clearly. To do this, divide the lines *OЛ* and *BK* into equal parts (for example, to 7) and number them. By connecting points of the same number on the lines *OЛ* and *BK*, we construct the *OBKЛO* working surface (Fig. 6).

In the construction of the working surface, it was taken into account that the left side of the referrers, that is, the beginning (for example, from *OB* to *ЛK*) lies on the straight line *OЛ*, which is made at an $\alpha_к$ angle to the horizontal.

Our next study will be devoted to the study of the effect of tipping on the width of the base working surface.

As can be seen from Figure 5, *A'B'C'* is equal to the width *b* of the sheared soil in a transverse vertical plane. Therefore, the base of the working part should be equal to the coverage width *b*. As *A'B'C'* moves to *A'B'C'* sheared soil, its width *b* decreases.

The relationship between the working width *b* of the working part and the base referrers, along the transverse vertical plane, and the angles of orientation relative to the horizontal can be explained according to Fig. 7 [7,8,9,10,11].

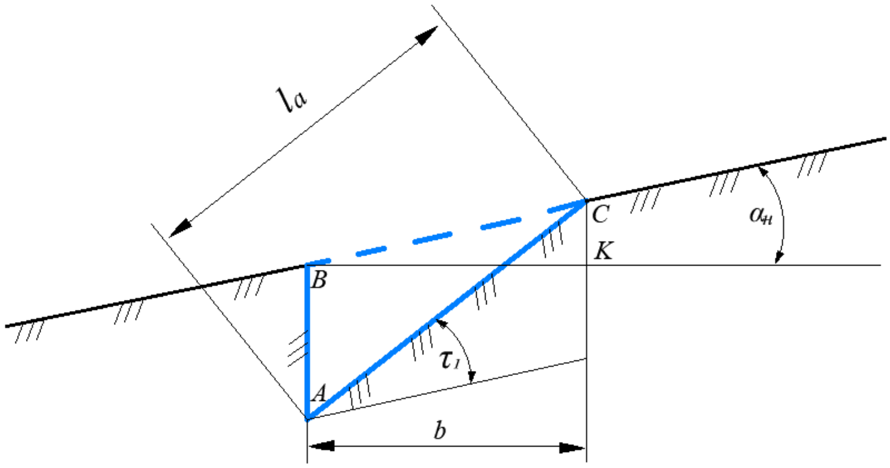

Figure 7. The scheme on the basis of the dependence of the width *b* of the device coverage on the angle τ_1 of the referrers of the base working surface

The beginning of the base on which the share is installed, that is, the referrer *AC*, after the stable condition of the sheared soil overturning is ensured, the process of rotation, resting on the point A^1 on the field surface, continues (see Fig. 5). During this period, the base width of the overturned sheared soil begins to decrease and this process continues. According to Figures 4 and 5, the dependence of the base width *b* of the sheared soil on the $\alpha_н$, τ_1 and δ_i angles can be written in the form of the following expression,

$$b = l_a \cos\left(\alpha_{\text{н}} + \tau_1 + \delta_i\right) \quad (3)$$

where the value of the angles that ensure its complete overturning after the δ_i–sheared soil is released to the field surface, degree.

First, according to the expression (3), the length of l_a is calculated in values of *b*=35 cm $\alpha_н$=10° , τ_1 =30° and δ_1=0°. Calculation results show that l_a=46 cm. The values of the *b* width at the next angles of δ_i are given in Table 1 [7,8,9,10,11].

Table 1

Values of the *b* width at the angles of δ_i

Identification	$\alpha_н$, degree	τ_1, degree	δ_i, degree	Calculation ılt, cm
b_1	10	30	10	29,4
b_2	10	30	20	23,0
b_3	10	30	30	15,6
b_4	10	30	40	7,8
b_5	10	30	50	-

The analysis of the table shows that the width of the base decreases with the increase of the installation angle of the referrer relative to the horizontal. And when the angle reaches 90°, it can be seen that there is no width.

Also, from the analysis of the expression (90), it can be seen that the width *b* is related to the angle δ_i in the form of a cosine function. Receiving the graph of the cosine function in the form *ВЛ*, it is possible to form the *ВЖТЛ* returner form. Then, in the form of *ОВКЛ*, the working surface is left as a device, its *ВЛК* part is removed (Fig. 8) [7,8,9].

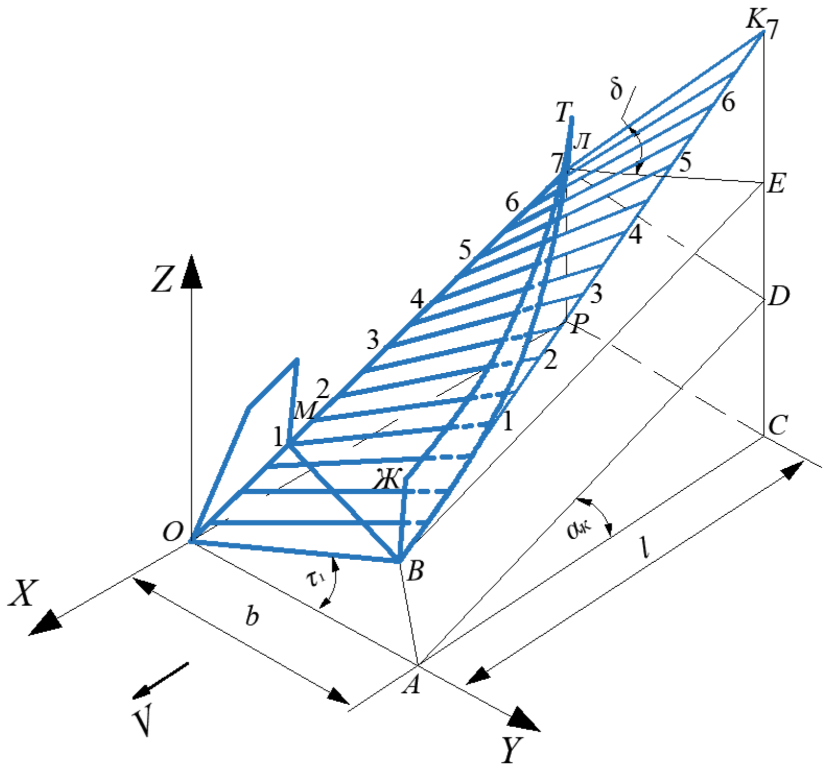

Figure 8. Axonometric diagram of the view of the device

On the basis of the research conducted on the construction of the working surface, it is possible to construct the law of change of the installation angle of the referrer relative to the horizontal.

The construction of the final *OBKЛ* working surface of the device begins with the development of its initial *OBEЛ* form. Because the beginning of the working surface referrers is located on its *OЛ* edge.

It is convenient to analyze the working surface of the proposed device by conditionally dividing it into two parts. In the first *OMB* section, the referrers are directed at an angle τ_1. This angle does not change until the 1-1 referrers. The following angle of the referrers is denoted by δ_i, and it increases from 0 to 50^o angles.

Unlike existing housing work surface referrers, the proposed device work surface referrers can be adopted as a straight line. Because in this process, the completeness of the pulverization and overturning of the sheared soil removed from the ditch is not very important for the technological process being carried out.

Based on the kinematic analysis of overturning of the sheared soil, each subsequent, for example, 2-2 referrer is increased to 1-1, and 3-3 to 2-2 etc. at a fixed angle of 10^o. This continued until the 7-7 referrer. Then the last 7-7 referrer is placed at an angle of 90^o relative to *OB//ЛE*.

If the angles of installation of the referrers relative to the horizontal are placed on the scale of 1^o =1 mm on the abscissa axis, and on the ordinate axis, the distance *OЛ* is set at intervals of 10 cm, and the graph shown in figure 9 is constructed [7,8,9].

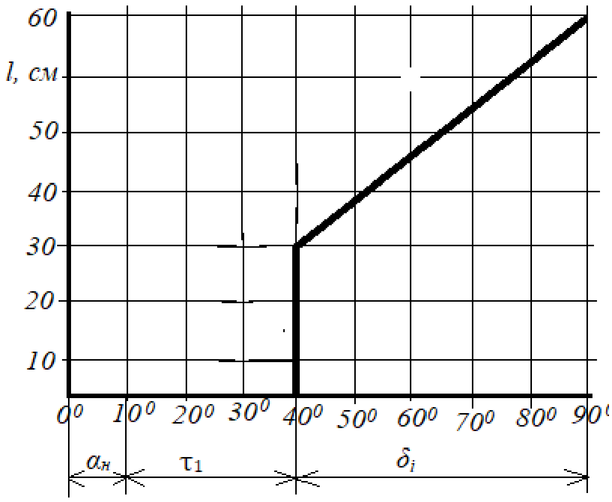

Figure 9. The law of changing the angles of installation of the referrers of the working surface relative to the horizontal

From the analysis of Figure 9, the distance goes from zero to 30 cm when the referrer is set at an angle of 40° to the horizontal. As the angle increases, so does the distance. They are connected to each other on the basis of the law of a straight line.

Based on the results of the above research, the first version of the device was prepared (Fig. 10) [7,8,9].

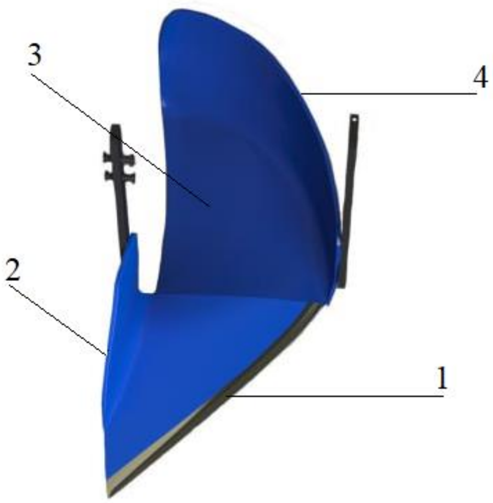

Figure 10. View of the developed device. 1-share, 2-blade, 3-base, 4-returner

Conclusion. To sum up, a garden located on a slope can prevent soil erosion by creating a ditch and a garden-bed between the rows. In order to open a ditch and create a garden-bed at the expense of the soil removed from it, the sheared soil is first taken to the field surface. A garden-bed is formed by turning the sheared soil to the downhill side of the slope. The use of the above technological process to prevent water erosion in the soil on sloping fields has its positive effect.

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