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THE ESTIMATION OF MECHANICAL REMOVAL OF SLOPE SOIL

P. A. Tonapetyan[1], **P. Yu. Gasparyan**[2]
[1]*Armenian National Agrarian University*
[2]*Shushi University of Technology*

The process of interaction of working organ and the soil has been studied to investigate the mechanism of soil removal in slopes and to prevent it. A mathematical model for evaluating mechanical soil removal in the slopes has been developed to determine the dimension of the movement of the soil (drill) removal both down and up depending on the slope and the change of the technological parameters of the working organ. Such equations were obtained by the application of which the slope removal will be prevented by the regulation of structural and kinematic parameters of the working organs of cultivating machines.

Key words: slope, soil erosion, furrow, spike, plowshare, drill, shift, parameter, trace.

Introduction

Landscape agriculture has not developed yet but it has quite sufficient amount of supplies in enlarging the additional production of highly qualified agricultural products.

The slope soils are subjected to intensive erosion and if necessary steps are not taken, those soils may become useless causing significant economic damage to agriculture.

It is necessary to study the procedure of interaction of working organ and soil for investigation and prevention of soil removal mechanism in slopes especially in case of relative removal of the soil over the surface of working organ.

Conflict setting

Many researchers have dealt with the studies of working organs of soil cultivation and soil interaction [1,2,3,4,5,6] taking into account the theories of V.P. Goryachkin and his followers about the interaction of soil and spike (two layered and three layered). However, there is still no definite consistent approach for determining the trace of soil removal over the working surface of spike. Some scientists think [3,5,6] that the soils move towards the furrow stood by the pedal of spike and some find that [8,9,10] the soil trace passes through the plowshare to the pedal.

Generally, the trace of relative movement of soil over the working surface of spike is suggested by η angle of cutting edge of plowshare (Fig.1) which, according to L. V. Gyachev [3] is defined by the following expression

$$tg\eta = tg\gamma \cos\varepsilon , \tag{1}$$

where ε is the angle of working surface of plowshare and furrow bed, γ is the angle of cutting edge and direction of soil removal.

While projecting the working organs of cultivating machines it is not accounted that these machines should also work in the slopes. Consequently, during the cultivation of these slopes with the working organs the corresponding agro technical requirements are violated resulting the worsening of the cultivation quality.

During the action of the working organ of minimal cultivation of the soil (particularly the arrowhead paw) in the lowlands, the tillage moves to the right and left symmetrically in the direction of movement during which no general movement of the soil is noted. While working on the slopes the soil moves more downslopes than upside resulting in mechanical removal of the soil [4,11,12].

The movement of the soil downslopes is conditioned by the impact of additional forces (Q) on the tillage

$$Q = G\sin\theta,$$

where G-is the weight of the tillage, θ-is the angle of the slope.

Let us theoretically research on the change of soil removal on the slope depending on the slope and the parameters of working organ.

Research results

During the soil cultivation with $ABCO$ trihedral spike the tillage turns to the working surface of the spike by S trace (Fig. 1). The same spike on the slope declines and takes AB_1C_1O position thus changing horizontal and vertical platforms and technological parameters. The trace of tillage movement is also rolling with the spike as a result of which η angle characterizing the spike gets various values in various positions.

The position of spike in space also changes under the impact of angular forces which make the trace of the tillage, declines for some more δ angle and takes AD_1' position.

As we can see in Fig. 1, the movement of the tillage down the slope increses $from\ OE$- $to\ OE_1'$. Up to the slope the movement decreases.

To determine the dimension of tillage movement we need to have the parameters of the spike.

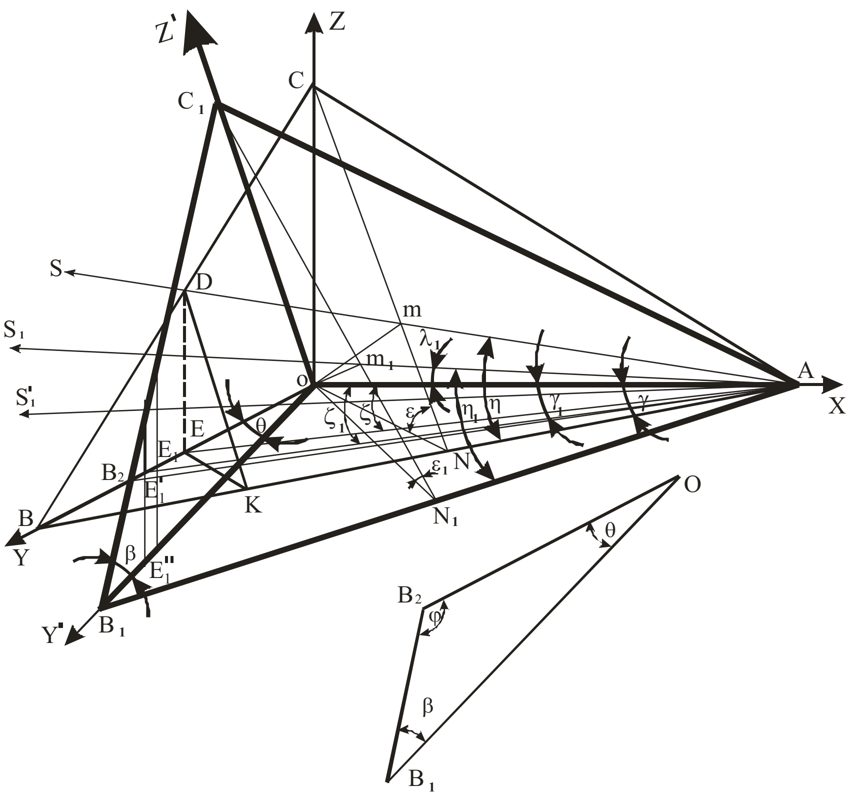

Fig. 1 The scheme of soil removal depending on slope

Taking into account that most working organs of cultivators of minimum cultivation of the soil are arrowhead paws, let us study the working organ with appearance of plowshare of B width which represents a part of trihedral spike (Fig.2).

We can see from Fig. 2 that the tillage movement on the slope is $\Delta_1 = OE_1''$ which can be determined by the following expression

$$\Delta_1 = OE_1'' = AO \cdot \frac{tg\xi_1}{\cos\theta} = AD_1' \cdot \frac{tg\xi_1 \cdot \cos\lambda_1}{\cos\theta},$$

or

$$\Delta_1 = B\frac{tg\xi_1 \cdot cos\lambda_1}{cos\theta \cdot sin\eta_1} \tag{2}$$

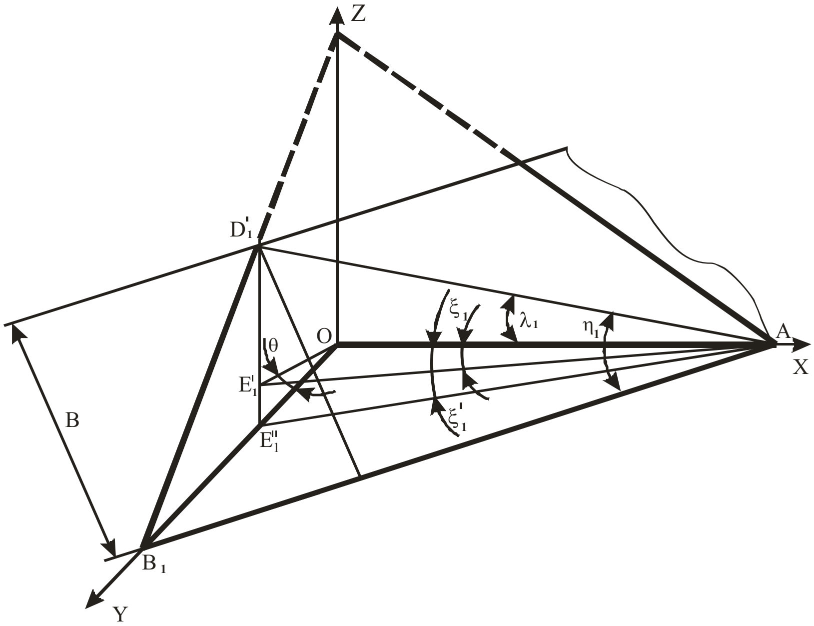

Fig. 2 The scheme of determining the tillage removal on slopes

If the $OABC$ spike (the part of arrowhead paw to down) declines to the width of the slope and takes OAB_1C_1 position, AB_2 line will become the trace of spike surface on OAB platform and γ_1 angle of current value of the angle (the angle of pushing side) depending on slope (θ). Let us determine the value of the angle. According to Figure 1 we can write

$$tg\gamma = \frac{OB}{OA}, \qquad tg\gamma_1 = \frac{OB_2}{OA} \ ,$$

where $$\frac{OB}{tg\gamma} = \frac{OB_2}{tg\gamma_1} \Rightarrow tg\gamma_1 = tg\gamma \cdot \frac{OB_2}{OB}$$

Taking into account that $= OB_1$, we will get

$$tg\gamma_1 = tg\gamma \cdot \frac{OB_2}{OB_1} \tag{3}$$

In

B_1B_2O triangle (Fig. 1) we will use the theorem of sinus getting the following

$$\frac{OB_1}{sin\varphi} = \frac{OB_2}{sin\beta} \quad \Rightarrow \quad \frac{OB_2}{OB_1} = \frac{sin\beta}{sin\varphi} \tag{4}$$

Taking into account formula (4), formula (3) will get the following expression

$$tg\gamma_1 = \frac{sin\beta}{sin\varphi} tg\gamma \tag{5}$$

From OB_1B_2 triangle let us determine φ angle

$$\varphi = 180° - (\beta + \theta), \quad \textit{consequently}$$

$$sin\varphi = sin(\beta + \theta) \tag{6}$$

Putting (6) formula into (5) we will get

$$tg\gamma_1 = \frac{\sin\beta}{\sin(\beta+\theta)} tg\gamma \tag{7}$$

The last expression will get the following expression for the arrowhead paw upside the slope

$$tg\gamma_1 = \frac{\sin\beta}{\sin(\beta-\theta)} tg\gamma \tag{8}$$

Let us discuss the current value of ε angle according to Fig. 3

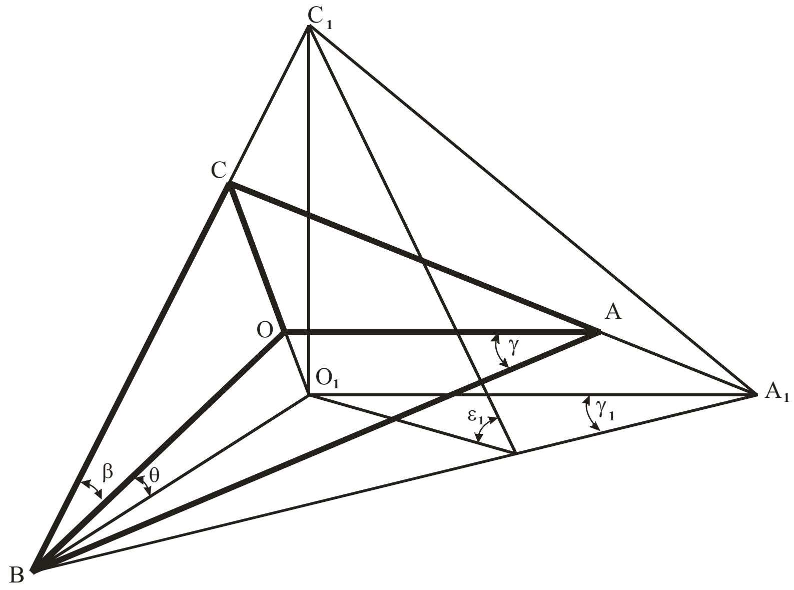

Fig. 3 The scheme of determining ε_1 angle

It is known that $tg\beta = tg\varepsilon \cdot cos\gamma$ [3]. For A_1BC_1 trihedral spike instead of β angle we will put $\beta+\theta$ angle and instead of γ angle we will put γ_1. So we can derive

$$tg(\beta+\theta) = tg\,\varepsilon_1 \cdot cos\gamma_1$$

$$tg\,\varepsilon_1 = \frac{tg(\beta+\theta)}{cos\gamma_1} \tag{9}$$

For the wing over the arrowhead paw we will have

$$tg\,\varepsilon_1 = \frac{tg(\beta-\theta)}{cos\gamma_1} \tag{10}$$

Let us use Fig. 1 to determine ξ angle formed by horizontal projection and direction of tillage removal according to which we can write

$$tg\eta = \frac{DK}{AK} = \frac{KE}{AK \cdot cos\varepsilon} = \frac{tg(\gamma-\xi)}{cos\varepsilon}$$

Changing the obtained expression we will get

$$tg\eta = \frac{tg\gamma - tg\xi}{(1 + tg\gamma \cdot tg\xi)cos\varepsilon}$$

Solving to $tg\xi$ we will get

$$tg\xi = \frac{tg\gamma - cos\varepsilon \cdot tg\eta}{1 + tg\gamma \cdot tg\eta \cdot cos\varepsilon} \quad (11)$$

Using formula (1), we will write the last expression in this way

$$tg\xi = \frac{tg\gamma - cos^2\varepsilon \cdot tg\gamma}{1 + tg^2\gamma \cdot cos^2\varepsilon}, \quad \text{or}$$

$$tg\xi = \frac{tg\gamma \cdot sin^2\varepsilon}{1 + tg^2\gamma \cdot cos^2\varepsilon}$$

(12)

Consequently

$$tg\xi_1 = \frac{tg\gamma_1 - cos\varepsilon_1 \cdot tg\eta_1}{1 + cos\varepsilon_1 \cdot tg\gamma_1 \cdot tg\eta_1} \quad (13)$$

Using 7, 8, 9 and 10 formulas and doing some mathematical changes, we will get

$$tg\xi_1 = sin(\beta + \theta) \cdot sin\beta \cdot tg\gamma, \quad (14)$$

$$sin\eta_1 = \frac{sin\beta \cdot cos(\beta + \theta)tg\gamma}{\sqrt{sin^2(\beta + \theta) + sin^2\beta tg^2\beta}} \quad (15)$$

Let us determine λ_1 unstable according to Fig. 1

$$cos\lambda_1 = \sqrt{1 - sin^2\gamma_1 \cdot sin^2\varepsilon_1} \quad (16)$$

After appropriate placements and certain transformations we will get

$$cos\lambda_1 = \frac{1}{\sqrt{sin^2\beta tg^2\gamma + 1}} \quad (17)$$

Placing 14, 15 and 17 formulas in (2) we will get the dimension of tillage movement

- up the slope

$$\Delta_1 = B\frac{tg(\beta + \theta)}{cos\theta}\sqrt{\frac{sin^2(\beta + \theta) + sin^2\beta tg^2\gamma}{sin^2\beta tg^2\gamma + 1}}, \quad (18)$$

- down the slope

$$\Delta_1 = B\frac{tg(\beta - \theta)}{cos\theta}\sqrt{\frac{sin^2(\beta - \theta) + sin^2\beta tg^2\gamma}{sin^2\beta tg^2\gamma + 1}} \quad (19)$$

Using the last formulas the graphics of changing the dimension of the tillage movement were derived depending on slope for various values of γ angle by plowshare and tillage movement ($\gamma = 30^o$ and $\gamma = 55^o$) (Fig.4).

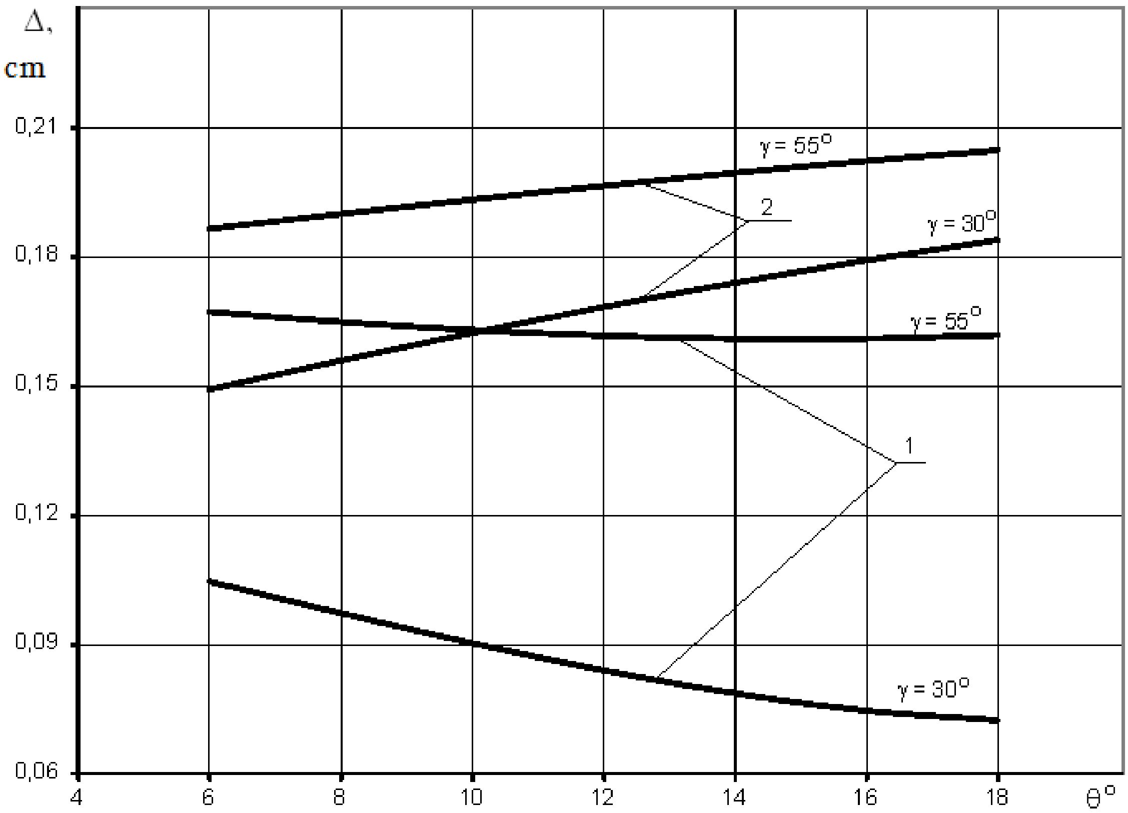

Fig. 4 Graphics of changing tillage removal on slope depending on the slope deviation
1- up to the slope, 2- down the slope

As we see from the graphics, parallel to the increase of deviation of the slope the size of tillage movement decreases. Therefore, the soil removal down the slope in case of big values of γ angle is bigger and up the slope is rather small which it is conditioned by.

Conclusion

1. The mathematical modelling of estimating the mechanical soil removal in slopes allows to determine the dimension of soil (furrow) and the change of technological parameters of working organs.
2. The obtained equations allow us to prevent the tillage movement by regulating the structural and kinematic parameters of working organs of soil cultivation.

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