THE PECULIARITIES OF THE WORK OF TILLAGE MACHINES ON THE SLOPING LANDS

Candidate of Technical Sciences, Associate Professor Viktor Pryshliak
Ukraine, Vinnytsia National Agricultural University
viktor.prishlyak@i.ua

Abstract: *Considered are the problematic issues of tillage on slopes and presented the methodological aspects of theoretical analysis and experimental research. The production testing of the work of tillage equipment in the circumstances is being taken into account for the conservation of soil fertility. It is considered that the ploughs are often used on sloping lands for primary tillage, although the use of special tools for subsurface of the soil conservation tillage is preferable. Given here are the scientific-theoretical and practical recommendations on the use of the complex contour tillage machines and drainage system in the agriculture fields with complex terrain.*

KEYWORDS: *SOIL, CROPS, CROP ROTATION, TILLAGE MACHINES, EROSION.*

***Introduction*.**

The development of tillers is inextricably linked with the zonal features of their use, where the important place is occupied by the difficult terrain conditions. Tillage processes on the horizontal sections at the optimum values of humidity and hardness of soil by existing machines are performed generally satisfactory. However, the work of soil-cultivating units is carried out not only on the flat fields, but also on slopes up to 5-7˚. The machine and tractor units with static stability margin about 35-40˚, may work with high quality in the fields with a slope just before 2-3˚. In hilly areas with steep cross slopes exceeding the specified value, due to the lack of special equipment for working in difficult terrain conditions, to carry out high quality production processes is not possible. In Ukraine, more than 95% of arable land is located on slopes up to 5˚, and the rest − 5-14˚. In some regions of the country the slopes which are steeper than 5˚ have a significant share − more than 20-40% [1].

Prerequisites and means for solving the problem.

Working conditions of agricultural machines on the same field with the hilly terrain vary depending on the direction of the movement: uphill, downhill, across a slope or hillside. From the point of view of minimizing erosion in sloping lands the movement of the tillage machines should be carried out across the slope.

However, it should be borne in mind that when driving across a slope there is a spontaneous withdrawal of tires caused by the lateral component of the force of gravity units, as well as the difference in rolling resistance forces of the upper and lower support elements along the slope unit. Disposed along with spontaneous slipping, occurs sliding of the machine wheels and its working bodies down the slope, which depends mainly on the magnitude of the angle of the slope, the load on the wheels, the physical and mechanical properties of the soil and the tire grip. As a result of the combined action of the side movement and sliding is broken the rectilinear motion of sustainable agricultural machines on a slope.

When the tillers are working on sloping lands, along with the stable movement should be considered the quality performance and especially the agro ecological ones. For example, when ploughing on slopes steeper than 4º occurs the displacement of soil up the hill, partial wrapping layer of soil by a plough body, and when working with soil turning to the base of the slope there is its shift to the bottom, which is adequate to the soil loss of 12 m^3/ha [1, 2].

In general, the quantitative assessment of erosion processes is given for the intensity of soil loss per unit area and per unit time, i.e. t/ha per year or mm/year. In these units is measured the rate of soil processes too. Comparing the rate of the soil loss with the rate of the soil formation, it is possible to have an estimate of the degree of danger of erosion. And if the intensity of erosive processes is below than the rate of soil formation, then the erosion of this field is not dangerous, although this is very rare.

Solution of the examined problem.

In conservation agricultural system with the contour-reclamation land use, the organization of the territory is depending on the steepness of the slopes which are differential by nature, according to which the arable land is divided into 3 groups. The first group of land − plain and slopes up to 3º. It is used for grain and other agricultural cultivated between rows crops, rotation of grain cultures. In farmlands with very rugged terrain is envisaged the reduction of cultivated crops and increased the amount of grains and herbs. This is due to varying soil protection efficiency of these crops. The second group of land − slopes from 3 to 7º. They are recommended for the use of catch crop rotations with the sowing of winter cereals and ardent, annual and perennial grasses and without row crops. The third group of land − more than 7º slopes. They are seeded by perennial grasses. The complex of the used tillers depends on the type of the growing crop, the sowing of which in turn depends on the steepness of the slope.

According to the profile of the slopes they can be divided into concave, convex and convex-concave. In the concave slope steepness gradually diminishes from the middle of the sole. The soil on it becomes more fertile as you approach the valley. A convex slope has relatively level ground at the top, it is lowered below the surface and in the lower part moves sharply into the valley or ravine. On the convex-concave slopes the steepest portion is spaced at some distance from the base. Over the steep part of the slope is again a flat area on which is deposited the fine earth, carried by the upper part of the slope with water or mechanical action supporting-running elements of tractor units.

For traffic conditions of the tillage machines by contours on the convex-concave areas of the slope change in the thickness of the fertile layer equals [2]

$$\Delta h_i = h_0 (1 - \frac{Y}{B_n}) \pm [1 - \frac{R_i}{R_i + Y}],$$

where h_0 − the initial thickness of topsoil; Y − distance movement of soil during processing; R_i − the radius of curvature at the point where the value is determined Δh_i; B_n − the bandwidth that is being processed. The "+" is used for the convex, and the sign "−" for the slope of the concave sections.

The intensity of the mechanical-technological erosion increases in proportion to the increase in the steepness of the slope α. If the main line of the slope is represented by a straight line and the value of α along the main line is constant, the velocity v and the displacement of soil along the (main line) generator are also constant. On the convex-concave areas, which occupy an important place in agriculture, the steepness of slope α on convex sections along the generators increases and decreases in concave areas. This affects both the stability of the machine movement, especially in the transverse direction of the slope, and the displacement of soil erosion particles downward the slope.

The surface of the field sloping lands include rocks, big pieces of land, macro- and microscopic irregularities. The particular importance is after their ploughing. From the bottom of the slope the surface of its own parts and where the macro roughness increases due to the steepness of the slope. At the same time there is a movement of smaller parts for large deviations. Considering the frictional force differential equation of motion of the material particles along an inclined plain takes the form [4]:

$$m\frac{d^2s}{dt^2} = m\frac{dv_\Pi}{dt^2} = mg\sin\alpha - fmg\cos\alpha, \quad (1)$$

where m – the mass of the particle; s – the way; t – time; v_n – speed; g – acceleration due to gravity; f – coefficient of friction.

Integrate the equation (1) twice with the initial conditions $v_n = v_o$; $s = 0$ when $t = 0$, we obtain

$$s = \frac{\cos\varphi}{2g\sin 9(\alpha-\varphi)}(v^2 - v_0^2),$$

where φ – is the angle of friction.

For the case $\varphi > \alpha$, the particle stops after a certain period of time:

$$t = t_1 = -\frac{v_0\cos\varphi}{g\sin(\alpha-\varphi)} = \frac{v_0\cos\varphi}{g\sin(\varphi-\alpha)}.$$

The path that the particle will take place at the same time is equal to:

$$s_{\max} = \frac{1}{2}\frac{v_0^2\cos\varphi}{g\sin(\varphi-\alpha)}. \quad (2)$$

At the same time

$$s = \frac{h}{\sin\alpha}, \quad (3)$$

where h – height to which the piece moves as it moves along the inclined plain until it stops.

Then, taking into account (2) and (3) the height to which a particle moves under the effect of the lateral component $mgsin\alpha$, can be represented in this form

$$h = \frac{1}{2}\frac{v_0^2\sin\alpha\cos\varphi}{g\sin(\varphi-\alpha)}.$$

On the plain, the angle of which $\alpha < \varphi$, the body cannot slide under the action of gravity, since the value of the friction will be more $fGcos\alpha$ term by $Gsin\varphi$ plain. Such a plain where the angle is less than the angle of friction is called self-locking.

Mechanical and technological erosion indicator for changing the thickness of topsoil Δh_i most intensively occurs in areas with convex contour and a convex manner.

In crop production technologies, the soil feels the impact of different working units and support-running elements of technical means of mechanization. The most energy-intensive process step is ploughing, which has long been very common in the farming system and was considered the primary tillage operation. Ploughing has some advantages and disadvantages [3].

When ploughing on sloping lands reservoir turn leads to destruction of protective vegetation cover of the soil, plant residues, which protect the structure of the soil from the devastating impacts of raindrops. Plant residues located on the surface of the field reduce the speed of displacement of soil particles with melting or rain water, which reduces erosion.

As known, the condition of the stable position of the soil layer during ploughing by ploughs which are not equipped with skimmers is the following:

$$\frac{b}{a} = k \geq 1{,}27,$$

where b and a – respectively, the width and thickness of the reservoir.

Limit value width to thickness ratio for formation on slopes depend on the field angle of inclination α and increase in the steepness of the slope value k_l increases. For example, with increasing steepness of the slope α from 0 to 5º limit steady position of the formation k_l increases from 1,27 to almost 1,33. This means that at constant widths body of plough, a ploughing depth should be reduced to achieve the desired quality of primary tillage.

When the ploughs work on the slopes, the special interest is the transverse stability of plough-body movement in the soil, which is the main source of friction landside of the furrow wall. The lateral component of the soil reaction on the working surface of the plough-body, taking into account the steepness of the slopes can be expressed by the formula:

$$R_y = R_x ctg(\gamma_0 + \varphi) + G_i sin\alpha,$$

where R_x – soil resistance force acting on it in the body of the plough layer cross-sectional plain; γ_0 – the angle between the blade and coulter groove wall; φ – angle of friction of the soil on the working surface; G_i – gravity of the plough, per one case.

The length of the landside is determined from the condition for sustainable progress of the plough in the horizontal plain and unloading racks housing the bending moment. For multihull ploughs landside length can be determined by the formula

$$l = \frac{b_\kappa\cos\varphi}{2\sin\gamma_o\cos(\gamma_o+\varphi)},$$

where b_κ – the width of the body; φ – angle of friction of the soil on the steel; γ_o – the angle between the blade and coulter field edged body.

To combat water erosion devices used to plough for the formation of holes, discontinuous furrows, ridges and other. The device for the formation of holes consists of a section with the hole-formation device and special hinge mounted on the plough frame at an angle of 55º to the direction of thrust. When creating oval holes on the field surface are formed oval holes, totaling 200-300 m^3 per 1 ha, which corresponds to 12-13 thousand. A hole length of 1,1-1,2 m and a width of up to 0,4-0,5 meters. Ploughing while making can be effective on side slopes 4-6º.

Cultivation of the soil without turning the soil formation, is widely used in soil conservation technologies of land processing includes such operations: metal-cutting blades, surface treatment, treatment of the combined units, chisel tillage, chisel processing, slotting, milling, deep-hole digging.

Metal-cutting blades tools better perform their function in the light and medium soils. On heavy soils they work worse, form a lump, don't move steadily. For quality work of metal-cutting blades tools the soil should not be over-wet. On heavy soils and at higher moisture content is recommended a wider use of rippers and chisel cultivators, gaps-maker, narrow holes tools, cutters.

When designing metal-cutting blades, you can implement a large number of options for the location of the working bodies, as the soil formation at work does not move to the side and does not turn around. But because these tools work on stubble backgrounds, containing a significant amount of crop residue on the field surface, it is important that the distance between the paws was enough for the free passage of plant debris and carrying out the process without jamming the soil.

Soil treatment without recourse to the reservoir was carried out with a chisel ploughs working bodies in the form of rippers with interchangeable bits of different designs. As a result of deep soil loosening and mixing 20-30 % of crop residues from the surface the ball 2-3 times increased its water soaking that prevented water erosion. Chisel hoeing to a depth of 50 cm was carried out during the rotation. Because of the depth of treatment below the arable layer of the energy intensity of the process of loosening the soil increased sharply.

A chisel tractive resistance P and other tools which loosen the soil to a depth that does not exceed the critical cutting depth can be determined by the formula [4]

$$P = fG + (k + \varepsilon v^2)S_k,$$

where f – coefficient of moving tools in the furrow; G – gravity gun; k – soil resistivity; v – working speed; S_k – sectional area of the loosened soil.

On sloping lands the system of the non-plough tillage included slotting the soil to a depth of 60 cm, with gaps of 3-4 cm in width and the distance between them more than 120-150 cm. The working bodies of the narrow holes maker worked in a cutting blocked mode.

Economically feasible is the use of combined units, which consist of a set of tools and execute within a single pass three or more basic operations – cultivation, disking of the soil, leveling, harrowing, compacting surface, etc. Each of these tools can be used individually for the intended purpose. Needle harrow BIG-3, for example, effectively loosens the soil in the spring to perennial grasses of the 2nd, 3rd year of cultivation.

The most beneficial to have the stabilization of movement for the tillage equipment which is carried out by the lateral soil reaction on the working bodies of the machine and wheels. Dimensions of the running wheels of tillers depend on soil conditions, implements design features, durability requirements.

A wheel experiences a radial load P_r and axial force P_o, applied to the bottom of the rim by the gauge. The magnitude of the axial force can be taken as

$$P_o = P_r \varphi_c,$$

where φ_c – friction coefficient. The axial force P_o creates point $P_o D/2$, which acts on the wheel, causing a bending stress. To increase traction with the ground applied spurs or flanges.

Pneumatic wheels mounted on the soil cultivated tools compared over metal ones have several advantages: they have somewhat lower traction resistance; they are less damaging to crops. Furthermore, application of pneumatic tires can improve speed and durability of the machine unit, due to the decrease of intensity shocks and bumps. Besides the tread of the tire must meet the following requirements: a good longitudinal and lateral grip on the rolling surface, sufficient self-cleaning grooves.

The above written scientific principles have important prerequisites for research and development activities of agronomic problems crop on fields with difficult terrain of crops, including promising bioenergetics groups − sugar beet, corn, wheat, triticale [5].

***Results and discussion*.**

In all soil protection technology is appropriate to include measures which are related to improving soil fertility by application of organic and mineral fertilizers. Therefore, the development of tillers on slopes should be considered as an opportunity to make fertilizer, organic mulch, as well as to perform the processing of the soil environment, including siderites and other crop residues.

Conclusion.

The theoretical and experimental studies have made it possible to clarify certain provisions of the peculiarities of soil cultivation on slopes, and to obtain new scientific results in this direction. In particular, the theoretical substantiation system tillers, their interaction of working organs and working elements running with the soil, taking into account the conservation of soil fertility. Soil treatment without rotating layers of the ground 2-4 times reduces the soil erosion. It was found that as the primary tillage can be used a variety of processing till methods across slopes with hole-making along each 5-6 m at a depth of 50-60 cm.

References

1. Amelchenko P.A, Ksenevich I.P., Guskov V.V., Yakubovich A.I. Wheeled tractors on slopes. – M .: Engineering, 1978. – 248.
2. Zaika P.M. The theory of agricultural machines. T. I (Part 1). Machines and tools for cultivation. – Kharkov: Eye, 2001. – 444.
3. Bondar S.M., Pryshlyak V.M., Shymko L.S. Management of complex machines in manufacturing processes cultivation: monograph. – Nizhyn LLC "Publishing" Aspect-Polygraph ", 2015. – 524.
4. Vasilenko PM. The theory of particle motion on rough surfaces of agricultural machines. – K .: UASKHN, 1960. – 284.
5. Pryshliak Viktor. Study of physical and technological processes of planting crops on slopes of priority agricultural crops in bioethanol industry / MOTROL: Motoryzacja i energetyka rolnictwa, An international journal on operation of farm and agri-food industry machinery. – Lublin–Rzesów: Mot. and Energ. Rol., Commission of Motorization and Energetic in Agriculture, 2013. – Vol. 15, No 5, 181-187.