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Selective wear of cuttings elements of working organs of tillage machines with realization of self-sharpening effect

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Summary. The clause of strengthening of cuttings elements is conditioning and realization of such self-organization process as a self-sharpening. Sharpening of horizontal and vertical cuttings elements of working organs of tillage machines (CE WOTM) is considered in many works, but not found out the terms of realization and nature of these processes in a sufficient measure. The processes of sharpening and blunting of CE WOTM are related mainly to the processes of wear. The change of type of CE in the process of wear is conditioned mainly a size and character of tearing down each of its bevel and by volume of destruction of cutting edge in the process of exploitation in the medium of soil and depends on character of co-operation in tribosystem " WOTM -soil".
Key words: self-organization, tribosystem, selective wear, cuttings elements, macro geometry, self-sharpening effect

INTRODUCTION

The results of researches and analysis of worn-out of WOTM shows that principal reason of refuses is a change of CE profile in the process of exploitation. In practice there are profiles of CE, resulted in Fig. 1

In most cases horizontal and CE is apeak placed sharp, their initial type is three-cornered (Fig. 1, a) and at the process of exploitation in soil it accepts other steady-state form (Fig. 1, b). Intensive wear is the results of its blunting of CE and increase of hauling resistance of WOTM. In such case there is a necessity to control the type of CE WOTM, strengthening of its working part and conditioning realization of sharpening effect. It is possible during the running-in and operating periods. Running-in is a process of change geometry of surface of friction and physical and mechanical properties of upper layers of material in an initial period of friction, showing up at permanent external terms in diminishing of friction force, temperature and intensity of wear. A concept "geometry of friction surface» is plugged in itself micro-roughness of surface and form (macro-geometry) of detail [8, 16]. Experimental confirmation of improvement of tribotechnical descriptions of friction surfaces at one of the running-in methods is presented in [29, 27]. The use of this high-efficiency method of forming of surfaces of details allows considerably increasing their resource [19, 28].

In this paper probed unsharp CE (Fig. 1, c), looking rotined after which, that their wears are less intensive than sharp (Fig. 1 a, b) unfortified CE. At certain operating time they had blunted (Fig. 1, d) and negative consequences are analogical.

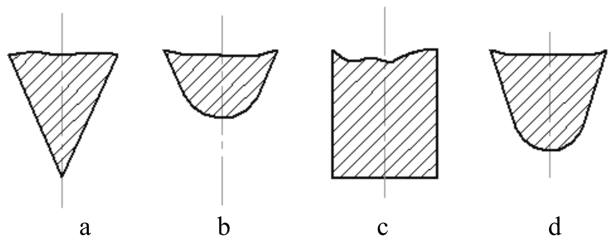

Fig. 1. Form of CE profiles: a – initial sharpen, c – initial blunten, b, d – after operating

OBJECTS AND PROBLEMS

Let's will utilize model approach of research of dynamics of forming of CE WOTM in the considered cases. The initial and eventual types of considered CE WOTM are resulted on Fig. 2.

Let it is sharp and unsharp CE WOTM works in the same soil, notably ($\varphi_s = \varphi_{us} = \varphi$ – are identical corners of friction) and at the same mode.

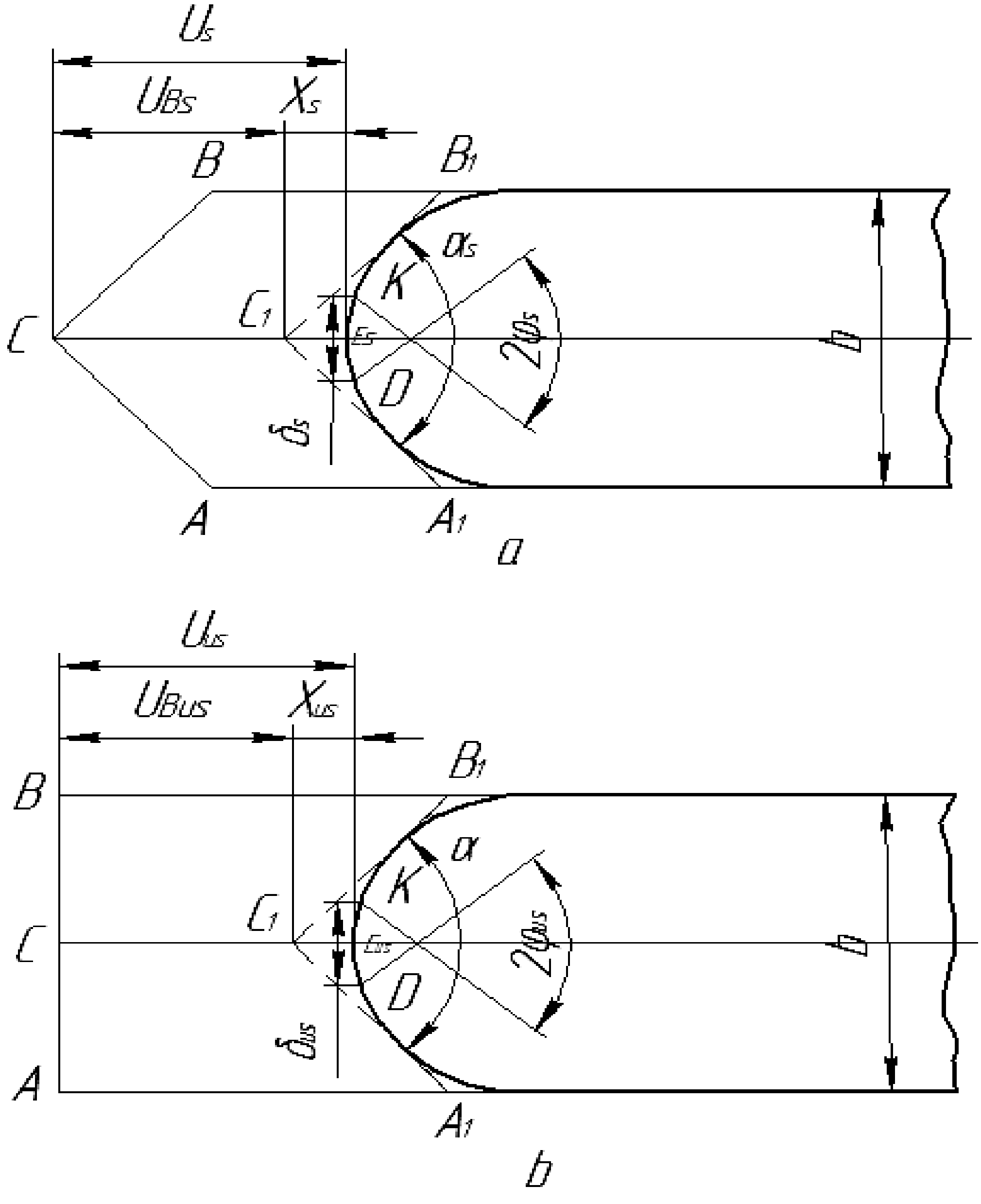

Fig. 2. Scheme of type′s change of unfortified sharp (a) and unsharp (b) CE WOTM

Will analyse character of wear of CE noted types to acquisition of identical corner of sharpening α ($\alpha_s = \alpha_{us}$). Thus will utilize length δ_s chords of edges arc of CE are with a central corner 2φ accepted in quality the criterion of sharpening of blade [17].

For considered CE, this criterion looks like:

$$\delta_s = 2x_s \frac{\sin{\alpha/2}\sin\varphi}{1-\sin{\alpha/2}}, \quad \delta_{us} = 2x_{us} \frac{\sin{\alpha/2}\sin\varphi}{1-\sin{\alpha/2}}. \quad (1)$$

For the moment of wear, when the type of CE is identical, will get:

$$\delta_s = \delta_{us}, \quad x_s = x_{us}.$$

Going out from the chart of change of types of CE and criteria of sharpening (2) quality, have:

$$u_s - u_{ds} = u_{us} - u_{dus}, \quad (2)$$

where: u_{ds}, u_{dus} - displacement of top sharp and unsharp CE, u_s, u_{us} - proper wear of these CE.

Experimental results testify that $u_s > u_{us}$, $u_{ds} > u_{dus}$, that at the wear of CE of displacement of top of unsharp CE carried out on a less size. Consequently from the results of researches distinctly, that CE is apeak placed it is possible not to sharpen, but expediently them to fix a working surface, to save the type of CE and create the terms of realization of sharpening.

Experimental researches after the changes of type of CE from a homogeneous metal in the process of exploitation shows that on the measure of wear are gradually stabilized and remain practically unchanging. The type of CE is formed does not depend on its initial type which was structurally given CE at making of WOTM from CE, from the thickness of CE (in possible limits) and from their material.

It is discovered that at the change of corners of setting of CE WOTM, physical-mechanical properties of soil, rate of movement of aggregate and at other terms the form of steady-state type can substantially change [23, 14].

Process of forming of types of CE at co-operating with the soil substantially depend on shock durability $\sigma_м$, material, sizes of wear and character of its distributing in edges points of CE, purchased in the process of exploitation (or preliminary formed) of sharpening corner α, thickness b, to pressure of soil p on CE, amounts of shots are on the plane of CE edge on unit of friction way L_{fr}, energies of blow of abrasive particles T, N·m, coefficient of proportion k, m^2/N:

$$\delta_s = 2(u_s - u_{ss}) \frac{\sin{\alpha/2}\sin\varphi}{1-\sin{\alpha/2}} = 2L_{fr}\left(n_{1s}\frac{T}{\sigma_м} - \frac{k_{1us} p u_s}{b}\right)\frac{\sin{\alpha/2}\sin\varphi}{1-\sin{\alpha/2}}, \quad (3)$$

$$\delta_{us} = 2(u_{us} - u_{sus}) \frac{\sin{\alpha/2}\sin\varphi}{1-\sin{\alpha/2}} = 2L_{fr}\left(n_{1s}\frac{T}{\sigma_м} - \frac{k_{1us} p u_{us}}{b}\right)\frac{\sin{\alpha/2}\sin\varphi}{1-\sin{\alpha/2}}. \quad (4)$$

Thus, on character of forming of type of sharp and unsharp CE substantial influence has wearproofness of material which they are made from, shock durability, way of friction, size and character of distributing of pressure of soil on a working surface.

Creation of sharpened CE, as unique for the terms of work on the different types of soil is a thorny enough problem [12]. Foreign and domestic producers for providing of capacity of wearing CE utilize the row of structural and technological methods [6, 10].

Let's will mark that making of detail from material of high wearproofness in general case is not a sufficient condition for achievement of the protracted term of maintenance of the given type of CE. At a correct choice constructions are utillized by the basic methods of increase of capacity of CE. For strengthening of workings surfaces which are most added wear, mainly composition materials are used.

The condition of strengthening of cuttings elements is conditioning and realization of such self-organization process as a self-sharpening. Sharpening of horizontal and vertical cuttings elements of working organs of tillage machine is considered in many works [2, 3, 4, 1, 7], but not found out the terms of realization and nature of these processes in a sufficient measure. The processes of sharpening and blunting of CE WOTM are related mainly to the processes of wear [9]. The change of type of CE in the process of wear is conditioned mainly a size and character of tearing down each of its bevel and by volume of destruction of cutting edge in the process of exploitation in the environment of soil and depends on character of co-operation in tribosystem " WOTM -soil".

Pressure of soil on CE WOTM is dynamic and it can be examined as a measure of intensity of continuous shots of abrasive particles on a working surface. A number and energy of their shots depend on a particle-size of soil.

In theory will ground the terms of realization of sharpening effect CE WOTM, in raising of flat task of change of form fixed CE at his wear in isotropic mass of abrasive averaging particles in size (Fig. 3).

Moving of fixed CE takes a place for axes OX. At the beginning of test an edge of CE is a rectilinear area ACB, and in the period of stabilizing of type of CE – by a curve $A_1C_1B_1$, with a top in a point C_1, farther with work of a withstand type A2C2B2, with a top C_2. After stabilizing of type CE wear of bevels takes a place congruent in accordance with the layers of CE. An edge of CE is in bevels A_1C_1 i C_1B_1 will has different speed of wear, as determines the first material bearing, and second – the fixed layer. In the process of realization of sharpening effect, the top of CE is displaced from the middle of thickness on a size Δ. As a wear on the width of CE much less than, than on length, accepted, that the general thickness of CE was saved: $b = const$.

For a constant process (Fig. 3), in obedience to work [5], it is possible to write down:

$$u_{uh}^{-1} \cdot b = 2u_h^{-1} \cdot k_{uh}\left(\frac{b}{2} + \Delta\right), \qquad (5)$$

where: u_{uh}^{-1}, u_h^{-1} – wearproofness of unhardened and hardened layers, Δ – displacement of top of CE edge is in relation to the middle of its thickness in the case of causing of the hardened coverage, $k_{uh}=H_h/H_{uh}$ – ratio of hardness the of unhardened and hardened layers of CE.

General wearproofness of fixed CE, wearproofness of bearing and composition layers it is possible to define on formulas [1]:

$$u_{ha}^{-1} = \frac{k_1 p}{b^2}, \quad u_h^{-1} = \frac{k_1 p}{b^2}, \quad u_{uh}^{-1} = \frac{k_1 p}{b^2}, \qquad (6)$$

where: k_1 – coefficient of proportion.

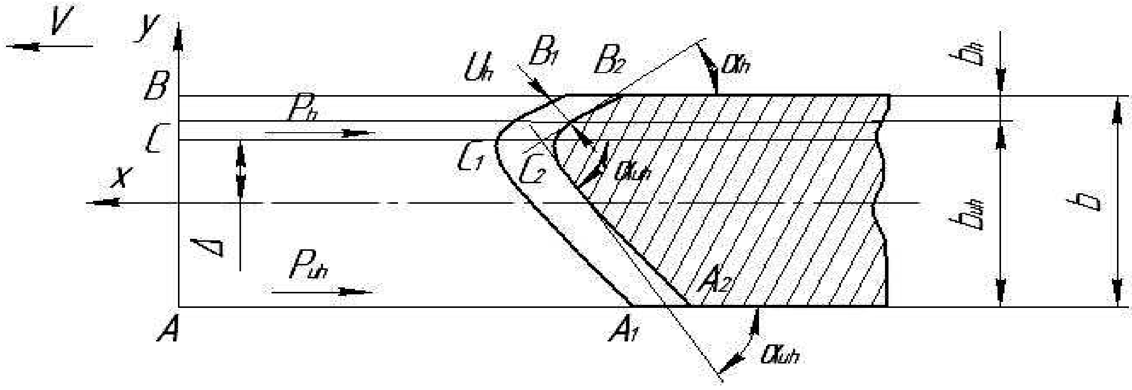

Fig. 3. Scheme of change of type of CE is with the inflicted composition layer of coverage in isotropic mass of soil

As a general loading on CE is evened:

$$P_{\Sigma}=P_h+P_{uh}, \qquad (7)$$

where: P_h, P_{uh} – efforts which operate to unhardened and hardened layers.

From formulas (6) certain efforts are evened:

$$P_{\Sigma}=\frac{b^2u_{ha}^{-1}}{k_1},\ P_h=\frac{b^2u_h^{-1}}{k_1},\ P_{uh}=\frac{b^2u_{uh}^{-1}}{k_1}. \qquad (8)$$

Will put (8) in (7) and will find the common size of wear of hardened CE:

$$u_{ha}=\frac{u_h u_{uh} b^2}{(u_{uh}b_h^2+u_h b_{uh}^2)}=\frac{v_{u\,h}\sigma_{u\,uh}b^2}{v_{u\,uh}b_h^2+v_{u\,h}b_{uh}^2}. \qquad (9)$$

Will put expression (9) in equalization (5) and after some transformations obsessed:

$$b=2k_{uh}\frac{(v_{u\,uh}b_h^2+u_h b_{uh}^2)}{v_{u\,uh}b^2}\cdot\left(\frac{b}{2}+\Delta\right). \qquad (10)$$

In a formula (10) take into account a coefficient $k_{vu}=\frac{v_h}{v_{uh}}$, what equals the relation of sizes of wears of composition and unhardened layers. After some transformations, have:

$$b=2k_{uh}\frac{(b_h^2+k_{vu}b_h^2)}{v_{u\,uh}b^2}\cdot\left(\frac{b}{2}+\Delta\right), \qquad (11)$$

where: relocation of CE edge top of bias in relation to its middle is evened from:

$$\Delta=\frac{b^3}{2k_{uh}(b_h^2+k_{vu}b_{uh}^2)}-\frac{b}{2}. \qquad (12)$$

Coming from the terms of realization of sharpening [18], it is possible to write down:

$$0\le\Delta\le{b}/{2}\ ,\quad \frac{b^3}{2k_{uh}(b_h^2+k_{vu}b_{uh}^2)}\ge\frac{b}{2}. \qquad (13)$$

After some simplifications have a next condition:

$$\frac{b^2}{k_h(b_h^2+k_{vu}b_{uh}^2)}\ge 1. \qquad (14)$$

As $b=b_h+b_{uh}=const$, taking into account the ratio of thickness of unhardened and hardened layers of CE, $k_b=b_h/b_{uh}$, will get:

$$\frac{k_b^2+2k_b+1}{k_{uh}(k_b^2+k_{vu})}\ge 1. \qquad (15)$$

The last condition combines all of complex of requirements of realization of sharpening effect horizontally and apeak placed CE: relation of hardness $k_{н}$ of hardened and unhardened layers, speeds of their wear k_{vu} and thicknesses of these layers - k_b.

Setting the relation of the noted descriptions glowed fixed and bearing, not in contempt of condition (15), it is possible to project such construction of two layers CE WOTM, which in the process of exploitation enables to realize the process of its sharpening.

Complex of values of correlations $k_{н}$, k_{vu}, k_b influences on relocation bias Δ of CE edge: with an increase of k_{vm} and $k_{н}$ it is increased, and with an increase k_b - diminishes accordingly.

Making of CE WOTM from a laminate after different structural charts is perspective and not enough studied. A widespread chart in practice is a chart S_1-H-S_2, that with a hard layer in the middle and by soft external layers. Such construction of CE has a row of advantages as compared to material homogeneous or double-coated CE: CE is stronger, as a capacity of it is improved for a flowage, shock viscidity and construction durability rises [15, 13]. In addition, next to sharpening of CE, crumbing of hard and fragile cutting layer is shut out, as it is a pinch-off between two plastic external layers of material.

M.I. Voloshko [26] developed the basic requirements to multi-layered CE, which consist in the following: CE has to self-sharpening, to be strong, lasting, cutting edge of CE must not be pressed, wrapped up, a hard layer must not be crumbed.

The epure of normal forces which operate on workings surfaces RE settles accounts for the concrete terms of work taking into account physical-mechanical properties of materials [22, 24]. After the got epure set character of distributing of normal forces on cutting edge and edges of CE and they can be applied for multi-layered CE.

Thickness, geometry, wearproofness of material and number of external (unhardeneds) layers of multi-layered CE it is possible to define on the basis of analysis the distributions of normal forces taking into account wearproofness of material of hard layer. The general thickness of hard (fixed) layer is accepted even the optimum thickness of cutting edge. The wearproofness of material of hard layer must be such in relation to unhardeneds layers, that CE is self-sharpening in the process of exploitation, that terms were executed discovered previously.

Will consider three-layered CE, that is self-sharpening working in the environment of soil with the thickness of cutting edge h_p and with a sharpening corner $\alpha=\alpha_1+\alpha_2$. The distribution of normal forces on CE in this case is resulted in Fig. 4.

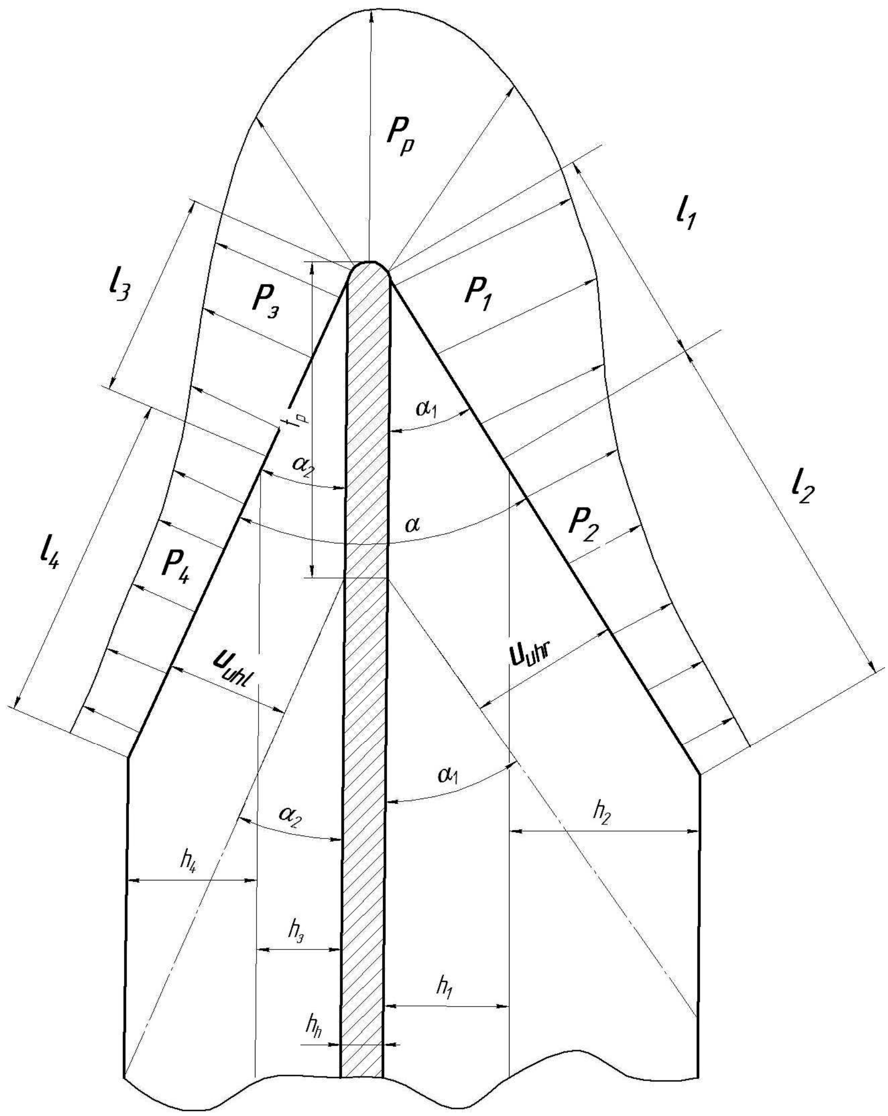

Fig.4. Scheme of multi-layered self-sharpening CE

The distribution of normal forces is divided into a few areas. A number of areas must be, on possibility, minimum, as after their amount the necessary amount of unhardeneds layers amount of which it must be such is determined, that as a result of wear there was not formation of appearances as a result of stepwise change of wearproofness of unhardeneds layers [25]. If CE is self-sharpening, as a result of wearing down there must be a parallel change of contour of it crosscut.

Will consider the linear wear of CE contour for normal to its surface. Thus the linear wear of surface of CE makes for a hard (cutting) layer $–U_h$, external unhardeneds layers from a right side – U_{uhr}, external unhardeneds layers from left U_{uhl}. Change a contour takes a place the cut of CE along the bisectricess of sharpening corner. For the maintainance of initial thickness of cutting edge and set corner of sharpening it must be the followings correlation are self-possessed linear wear of cutting (fixed) and unhardeneds layers:

$$\frac{u_{uhr}}{u_h} = \sin\alpha_1 ,$$

$$\frac{u_{uhl}}{u_h} = \sin\alpha_2 ,$$

$$\frac{\sin\alpha_1}{\sin\alpha_2} = \frac{u_{uhr}}{u_{uhl}} . \qquad (16)$$

Linear wear of CE layers, determined from equalization of Khruschova-Babicheva for an abrasive wear [15]:

$$\frac{du}{dL_{fr}} = kp , \qquad (17)$$

where: du — the linear wear for normal to the surface of friction, dL_{fr}– way of friction, p - contact pressure, k_a - coefficient of wear, which depends on composition and amount of abrasive, wearproofness of material and other factors. In the first approaching accept, that the wearproofness is straight proportional hardness of material, and that rate of movement of abrasive particles identical on all areas of CE. Thus basic conformity to the law of abrasive wear can be given:

$$u = \frac{k_a p L_{fr}}{w_{ha}} , \qquad (18)$$

$$k = \frac{k_a}{w_{ha}} ,$$

$$L_{fr} = vt ,$$

where: υ – rate of movement of particles of soil along the CE, k_a – coefficient of wear ability of soil, ω_{ha} – wear resistance of material, t – duration of test.

Using dependence (18), will define the linear wear of every layer of CE on the proper areas which the epure of normal forces is divided. The linear wear of hard (cutting) layer is evened:

$$u_h = \frac{k_a p_h L_{fr}}{w_h} . \qquad (19)$$

The linear wear of unhardeneds layers, located on the right side of CE, makes:

$$u_{uh1} = \frac{k_a p_{uh1} L_{fr}}{w_{uh1}}, \; u_{uh2} = \frac{k_a p_{uh2} L_{fr}}{w_{uh2}} . \qquad (20)$$

The proper linear wear of unhardeneds layers, located on left side of CE, is evened:

$$u_{uh3} = \frac{k_a p_{uh3} L_{fr}}{w_{uh3}} ,$$

$$u_{uh4} = \frac{k_a p_{uh4} L_{fr}}{w_{uh4}} . \qquad (21)$$

As a corner of sharpening of self-sharpening CE remains unchanging in the process of wear and a change of contour takes a place along the bisectricess of corner α, have:

$$\sin\alpha_1 = \frac{u_{uh1}}{u_h} = \frac{u_{uh2}}{u_h} . \qquad (22)$$

From other side:

$$\sin\alpha_1 = \frac{\overline{p}_{uh1} w_h}{\overline{p}_h w_{uh1}} = \frac{\overline{p}_{uh2} w_h}{\overline{p}_h w_{uh2}}. \qquad (23)$$

Like for sinα2, get:

$$\sin\alpha_2 = \frac{u_{uh3}}{w_h} = \frac{u_{uh4}}{u_h}. \qquad (24)$$

$$\sin\alpha_2 = \frac{\overline{p}_{uh} w_h}{\overline{p}_h w_{uh}} = \frac{\overline{p}_{uh4} w_h}{\overline{p}_h w_{uh4}}. \qquad (25)$$

Value $\overline{p}_h$, $\overline{p}_{uh1}$, $\overline{p}_{uh2}$, $\overline{p}_{uh3}$, $\overline{p}_{uh4}$ is determined from the epure of the normal loading, as mean values of pressure on the selected areas.

As initial at designing of CE is wearproofness of hard (cutting) layer, from expressions (23), (24) it is possible to define necessary wearproofness of unhardeneds layers of CE:

$$\omega_{uh1} = \frac{A\overline{p}_{uh1}}{\sin\alpha_{uh1}},\ \omega_{uh2} = \frac{A\overline{p}_{uh2}}{\sin\alpha_{uh2}},$$

$$\omega_{uh3} = \frac{A\overline{p}_{uh3}}{\sin\alpha_{uh3}},\quad \omega_{uh4} = \frac{Ap_{uh4}}{\sin\alpha_{uh4}}, \qquad (26)$$

where: $A = \frac{w_h}{\overline{p}_h}$.

Coming from geometrical correlations, the thickness of unhardeneds layers is evened:

$$h_{uh1} = l_1 \sin\alpha_1,\ h_{uh2} = l_2 \sin\alpha_1,$$

$$h_{uh3} = l_3 \sin\alpha_3,\ h_{uh4} = l_4 \sin\alpha_4, \qquad (27)$$

where: l_1, l_2, l_3, l_4 – proper areas of loading of unhardeneds layers.

CONCLUSIONS

1. Self-organization in a due form takes a place proportionally to pressure and provides a self-sharpening effect.
2. The considered method exposes the generals of effect of sharpening of multi-layered CE, and enables to develop the algorithm of its optimum designing.

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ИЗБИРАТЕЛЬНЫЙ ИЗНОС РЕЖУЩИХ ЭЛЕМЕНТОВ РАБОЧИХ ОРГАНОВ ПОЧВООБРАБАТЫВАЮЩИХ МАШИН С РЕАЛИЗАЦИЕЙ ЭФФЕКТА САМОЗАТАЧИВАНИЯ

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Аннотация. Условием упрочнения режущих элементов является создание условий и реализация такого процесса самоорганизации как само затачивание. Самозатачивание горизонтальных и вертикальных режущих элементов рабочих органов почвообрабатывающих машин рассмотрены во многих работах, но условия реализации и природа этих процессов не обнаружены в достаточной мере. Процессы самого заострения и затупления РЭ РОПМ связанны в основном с процессами изнашивания. Изменение профиля РЭ в процессе изнашивания обусловлено в основном величиной и характером износа каждой из его фасок и объемом разрушения режущей кромки в процессе эксплуатации в среде почвы и зависит от характера взаимодействия в трибосистеме "РОПМ-почва".

Ключевые слова: самоорганизация, трибосистема, избирательный износ, режущие элементы, макрогеометрия, эффект самозатачивания