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ENSURING THE EQUISTABILITY OF THE TILLAGE TOOLS WEAROUT

The paper considers the elaborated measures, aimed at ensuring the equistability of the wearout and reaching the effect of selforganization of the cutting elements of the reinforced V-shaped sweeps that leads to the reduction of the tractive resistance and decrease of the fuel consumption by the mobile energy facility.

Soil environment, where V-shaped sweeps function, influence greatly the regularities of the wearout and formation. Wearout of the tillage tools occurs unevenly, that leads to their premature rejection. Solution of the problem of ensuring higher durability to abrasive wear is achieved due to the application of the reinforcing technologies. All the available methods of reinforcements are suggested for the specific operation conditions and do not take into consideration possible change of the conditions and operation models.

For achieving the equistability of wearing- out it is necessary that the wear resistance of the tillage tools surfaces was proportional to the intensity of the abrasive wear in all the local zones. Uniform wearing-out of all the friction surfaces must provide long saving of the initial form and provide the effect of self-sharpening of the tillage tools.

Determination of the character and peculiarities of the wearing process of the serial V-shaped sweeps was carried- out at three types of soils, using the cultivator «John Deere 2210»). For study serial V-shaped sweeps, made of the steel 28MnB5 and steel 65Г were used. As a result of the studies, carried out wear distribution line was established, on its base measures, aimed at ensuring wearing- out the equistability and achieving self-sharpening were determined. Reinforcement of the V-shaped sweeps was performed by means of the electrodes T-620, T-590 and M-Fe 6 according to the elaborated schemes.

As a result of the application of the suggested measures increase of the wearing-out equistability on sandy loam soils is observed within the limits of 6…9%, on clay loam soils – 42…49%, on light clay – 25…36%. Self organization of the cutting elements of the reinforced V-shaped sweeps results in the decrease of the tractive resistance and fuel consumption by the mobile energy facility on average by 11%. Application of the reinforcing technologies enables to increase wearing-out equistability of the V-shaped sweeps of the cultivators by 9…49%.

Key words: *equistability, abrasive wear, soil, V-shaped sweeps, tillage tools.*

Significance of the studies carried out

Provision of the wear equistability of the parts of agricultural machinery, subject to the intensive abrasive wear is an important task for the design, production and maintenance. Complex character of this problem solution is connected with the impact of various factors on the process of abrasive wear, change of the parts properties and abrasive environment in the process of functioning. In agricultural sphere, taking into account modern trends to the increase of soil tillage speed, the problem of provision the equistability of the tillage tools wear is of great importance. Thus, the conclusion can be made regarding the significance of the investigated subject and the need of its further study.

Aim and task of the research. Object and subject of the research

Aim of the given scientific work: substantiation of the complex approach to the provision of wear equistability of the tillage tools (on the example of V-shaped sweeps of the cultivators).

For the realization of this aim main tasks are to be solved:

– study the characteristic features of serial V-shaped sweeps wear, depending on the conditions and operation models;

– develop measures to provide wear equistability and achieve the self-sharpening effect of V-shaped sweeps of the cultivator;

– perform field tests and develop recommendations for agricultural producers.

Object of the research: wearing process of working parts of the tillage machines.

Subject of the research: regularities of the geometric parameters of the tillage machines working parts change, depending on the conditions and operation modes.

Analysis of the latest studies

In the process of tillage machines operation wearing of the working parts occurs as a result of their interaction with the soil environment. Wear of the working parts takes place unevenly, that leads to their premature rejection. For instance in share-sweep working parts nose part is worn more intensively (Fig. 1).

Solution of the problem of providing higher resistance to abrasive wear is achieved as a result of application of the reinforcing technologies [1 – 8]. In the study [1] it is suggested to carry out the reinforcement of the local zones of V-shaped sweeps, exposed to intensive abrasive wear, by means of electrodes T-590 and T-620, using the schemes, shown in Fig. 2.

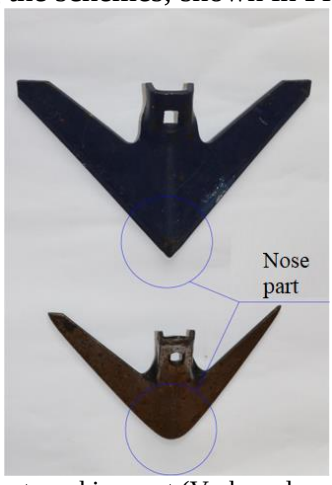


Fig. 1. New and worn out working part (V-shaped sweep) of the tillage machine

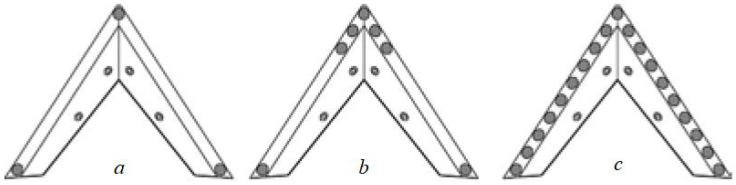


Fig. 2. Schemes of the point strengthening of the V-shaped sweeps: a - strengthening of the nose part and wings ends, providing effective width; b – intensive strengthening of the nose part of the cultivator sweep and wings ends; c – strengthening of the wings of the cultivator sweeps along the total length with a step of 25 mm [1]

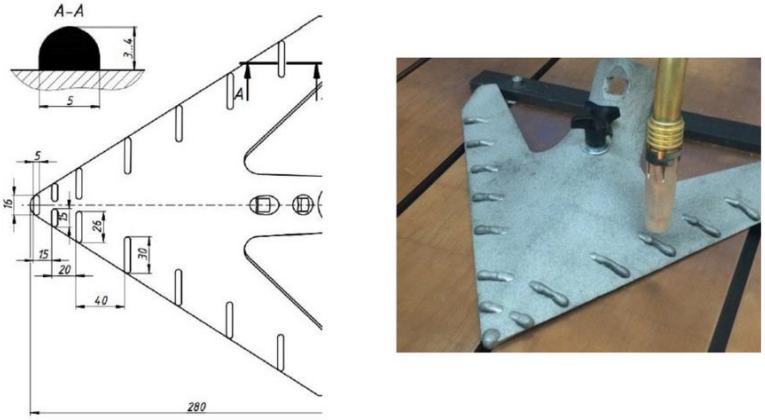
As a result of the studies, carried out, it is established that the least wear of the V-shaped sweeps is obtained, using the third scheme of strengthening (Fig. 2, c) [1].

Researchers [2] suggested for the improvement of soil tillage quality, reduction of the tractive resistance and wear resistance enhancement to manufacture the working parts of the curved shape and perform point strengthening, using electrode T-590 (Fig. 3).

Fig. 3. Experimental cultivator V-shaped sweeps: monometal with curved shape of the blade; b - experimental with low local displacement of the blade; c, d - experimental with upper local displacement of the blade [2]

As a result of the research, carried out, it is established that the improved profile of V-shaped sweep enables to reduce the tractive resistance 1,25…1,32 times and provides the reduction of clogging with the soil and plant remains 1,6 times as compared with the serial one. Upper local strengthening of the blade provides the reduction of wear value almost 2 times as compared with the serial sample and 1.13 times – with the variant of the local strengthening of the blade [2].

Method of increasing the wear resistance of the V-shaped sweeps by means of deposit welding of wearproof rollers of the rectangular form, namely on the nose, wings and blade part is suggested (Fig. 4) [3, 4].



a b

Fig. 4. Scheme of wear-resistance rollers location (a) and deposit welded V-shaped sweep of the cultivator [3, 4]

Technology of chemical-thermal treatment of the surface, namely boronation is widely used for strengthening the cutting edges of the V-shaped sweeps of the tillage machines. Using this technology, hard layer of 300…600 μm of depth is obtained, it has high resistance to the abrasive wear [3, 5].

To improve the durability of the working parts of the tillage machines, the technology of the deposit welding of the working surfaces with hard alloys of sormite type got wide application [8, 9].

In our country and abroad methods of improving wear resistance of the working parts of the tillage machines as a result of usage the concentrated flows of energy are known [7]. For instance, deposit welding by means of the alloy ПС-14-60 + 6 % B4C reduces the wear 1.7 – 1.8 times, as compared with the inductive deposit welding [10].

All available methods of strengthening are suggested for the specific operation conditions and do not take into account possible change of the conditions and operation modes. First attempts of taking iconsideration these conditions and operation modes while choosing the parameters of strengthening were made in [8].

For achieving the wear equistability it is necessary that wear resistance of the working parts surface was proportional to the intensity of the abrasive wear in all local zones. Uniform wear of all the friction surfaces must provide as long as possible maintaining of the initial form and give the effect of self-sharpening of the working parts of the tillage machines.

Studies of wear equistability provision and self-sharpening of the working parts of the tillage machines at different time were carried out by A. Sh. Rabinovych [12], Severnev M. M. [11], Kozachenko O. V. [6], Aulin V. V. [7], Tkachov V. N. [9], Borak K. V. [8] and others.

For the first time self-sharpening working parts of the tillage machines were introduced in the USA (1847) [13]. In the post-Soviet space the technology of their manufacture for the first time was described in the works of A. Sh. Rabinovych [13], who suggested the criterion of self-sharpening:

$$\omega = \frac{\varepsilon_2 s_2}{\varepsilon_1 s_1} \quad (1)$$

where s_1, ε_1 – is thickness and wear resistance of the strengthened metal; s_2, ε_2 – is thickness and wear resistance of the basic metal [12].

As a result of the studies, carried out, it is established that the optimal value of ω criterion must be 1.5 [12].

Tkachev V. M. determined four conditions for achieving the self-sharpening effect of share-blade working parts of the tillage machines [9]. In some works doubts, regarding the correctness of the suggested conditions of self-sharpening for all types of soils and operation modes are expressed [8, 10]. The greatest doubts generate the fourth condition for achieving the self-sharpening effect: strengthening must be subjected the edge of the blade, exposed by the least wear. In the works [14, 15, 16] it is proposed to perform the strengthening of the internal side of the V-shaped sweeps, and in the works [17, 18, 19], on the contrary, it is proposed to strengthen the external side.

One of the ways of achieving wear equistability and self-sharpening process of the working parts of the tillage machines is the application in the process of their design the biological prototype [20]. Nowadays there exists full-fledge science-bionics, based on the usage of the biological principles for the construction of the engineering systems.

Promising direction in the sphere of manufacturing self-sharpening working parts of the tillage machines is the application of the so-called «Self-sharpening» materials. These materials are produced on the base of tungsten, this determines their high price and prevents them from the introduction into large-scale production for manufacturing of the working parts of the tillage machines.

In the process of analysis the state of the problem of the provision of wear equistability of the working parts of the tillage machines it was established:

1. Studies, carried out, are of local character, i.e., they can be applied only for certain conditions and operation modes.

2. Impact of soil-climatic conditions and operation modes on the wear equistability and achieving the self-sharpening effect of V-shaped sweeps of the cultivators is not taken into account.

Program and technique of the research

Program of the research contained the following stages:

– study the character of serial V-shaped sweeps of the cultivators wear in the process of operation at different types of soils;

– determine the impact of the operation modes on the wear pattern of V-shaped sweeps of the cultivators;

– develop measures for achieving wear equistability and self-organization effect of V-shaped sweeps of the cultivators, taking into account the conditions and operation modes;

– perform field testing of the suggested methods and modes of improving the equistability of the V-shaped sweeps of the cultivators;

– give technical-economic assessment of the suggested measures, aimed at provision of wear equistability and achieving self-sharpening effect.

Determination of the character and peculiarities of wearing process of serial V-shaped sweeps was performed at three type of soil, using the cultivator «John Deere 2210» (Fig. 5).

For study serial V-shaped sweeps, made of steel 28MnB5 and steel 65Г were used. As a result of the studies , carried out, the wear distribution line was established, on its base, measures, aimed at provision of wear equistability and achieving self-sharpening effect were determined.

Strengthening of the V-shaped sweeps was performed by the electrodes T-620, T-590 and M-Fe 6 according to the developed schemes.

Fig. 5. Cultivator «John Deere 2210», used for the determination of the peculiarities of V-shaped sweeps wear on different types of soils

In the process of the study the working parts of the tillage machines, shown in Table 1, were used.

Table 1

Working parts, used in the research of wear equistability

Working part of the tillage machine	Soil		
	Sandy loam soil	Medium-textured loam	Light clay
V-shaped sweep (material of the V-shaped sweep + wear resistance coating)	28MnB5 65Г 65Г+Т-620 65Г+Т-590 65Г+М-Fe 6		

Strengthening of the V-shaped sweeps was performed by manual arc surfacing by the coated electrodes M-Fe 6, T-620 and T-590 (Table 2).

Table 2

Chemical composition of wear- resistant layer on the surface of V-shaped sweeps of the cultivator

Chemical element	Electrode		
	M-Fe 6	T-620	T-590
Mn	≤3.0	1 – 1.5	1 – 1.5
Si	-	2 – 2.5	2 – 2.5
C	≤2.5	2.9 – 3.5	2.9 – 3.5
P	≤0.04	≤0.04	≤0.04
S	≤0.04	≤0.035	≤0.035
Cr	≤10	22 – 24	22 – 27
Ti	-	0.5 – 1.5	-
B	-	0.5 – 1.5	0.5 – 1.5
Mo	≤3.0	-	-
Nb	≤10	-	-

V-shaped sweeps of the cultivator, manufactured from steel 65Г were subjected to heat treatment (volume quenching 820 – 840 ºС and medium-temperature tempering at the temperature of 450 – 470 ºС).

Results of the studies

As a result of the wear process study of serial V-shaped sweeps of the cultivator sharpening angles of the blade are determined, taking into account the type and aggregative state of the soil (Table 3).

Table 3

Sharpening angle of monometallic V-shaped sweeps of the cultivator (material- steel 65Г)

Soil	Sharpening, grad
Sandy-loam soil	17 – 21
Sandy-loam soil (fluff soil)	16 – 19
Medium-textured loam	23 – 25
Medium-textured loam (fluff soil)	22 – 23
Light clay	31 – 38
Light clay (fluff soil)	27 – 31

Sharpening angle of V-shaped sweeps differs along the total length of the cutting edge, this can be explained by the different value of the specific pressure of the soil on the local zones of the blade. The results of the study of the serial working parts wear process enable to make a conclusion that the serial working parts, operating on sandy and sandy-loam soils are able to perform self-sharpening. Dulling of the V-shaped sweeps is observed while their wearing on heavy-textured soil.

As a result of wearing the cutting edge of the V-shaped sweeps of the cultivator gets the form of the natural wear, but such form does not always lead to the decrease of the traction resistance of the machine. Assessment of the traction resistance of the unit was carried out by the specific fuel consumption of the mobile energy facility. Fuel consumption during operation of the machine with new V-shaped sweeps was taken as a reference (Fig. 6).

From Fig. 6 the conclusion can be made that in the process of operation of monometallic (serial) V-shaped sweeps of the cultivators on sandy and sandy-loam soils the process of self-organization of the working part occurs that leads to the reduction of the traction resistance and, correspondingly, to the decrease of the specific fuel consumption of the mobile energy facility. On heavy soils (clay loam and clay soils) the process of self-organization of the V-shaped sweeps of the cultivators in wear process, results in the growth of traction resistance of the machine and, accordingly, to fuel consumption growth.

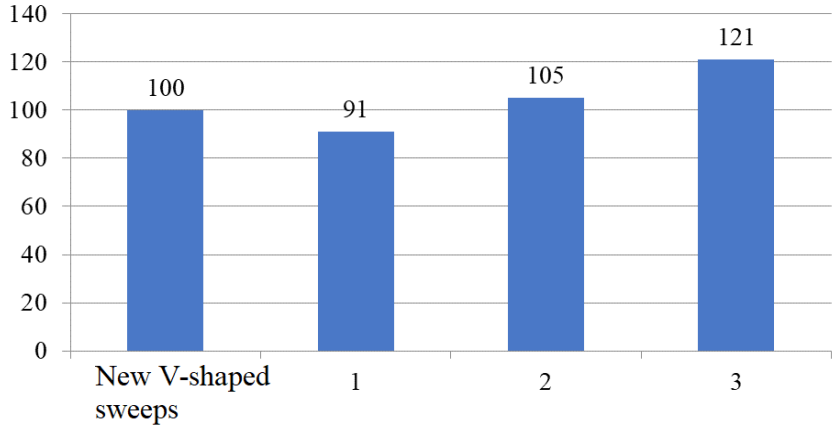


Fig. 6. Specific fuel consumption by mobile energy facility, aggregated with the cultivator «John Deere 2210»: 1 – on sandy-loam soils; 2 – on clay loam soils; 3 – on light clay (run 10 ha)

According to the results obtained, of the determination of V-shaped sweeps wear pattern the following conclusions can be made:

– for V-shaped sweeps, operating on clay loam and clay soils, developing measures, aimed at providing wear equistability it is necessary to develop measures, aimed at the control of the abrasive wear process, realizing self sharpening effect;

– for V-shaped sweeps, operating on sandy and sandy-loam soils, main task is to provide equistable wear of all local zones of the working part;

– developing measures, aimed at providing wear equistability of V-shaped sweeps of the cultivators it is necessary to take into account the conditions and operation modes.

In the process of the design of equistable V-shaped sweeps of the cultivators with the realization of the blade self-sharpening effect, main indices are wear resistance of the surfacing material and basic material, as well as their geometric parameters.

As it was mentioned above, it is established that optimal value of ω criterion must be 1.5 [12]. Studies, carried out by the author allow to determine more precisely this criterion, taking into account the operation conditions (Table 4).

Table 4

Values of ω criterion for V-shaped sweeps of the cultivator, taking into account the operation conditions

Soil	Criterion ω
Sandy-loam soil	1.5 – 1.6
Sandy-loam soil (fluff soil)	1.3 – 1.4
Medium-textured loam soil	1.4 – 1.5
Medium-textured loam soil (fluff soil)	1.25 – 1.35
Light clay	1.35 – 1.45
Light clay (fluff soil)	1.2 – 1.3

With the reduction of the abrasive properties of the soil and its hardness the strict trend to the decrease of ω criterion is observed. This can be explained by more uniform loading on the cutting edges of the working part.

Studies were carried out on the soils where stone inclusions are not present. On the soils, littered with stones, ω criterion must be considerably increased to eliminate the possibility of appearing harder layer and breaking of the working part during the interaction with stone inclusions.

A. Sh. Riabinovych in his works noted that ω criterion must be of the same value along the total length of the cutting edge [12] of the working part of the tillage machine. Strengthening according to such scheme can not provide necessary self-sharpening along the total length, as it does not take into account the peculiarities of wear of the local zones of the working organ. This relation must take into consideration not only the necessity of the self-sharpening but also the need of wear equistability of the V-shaped sweep of the cultivator.

For achieving the effect of self sharpening and wear equistability it is recommended to divide the V-shaped sweep into two local zones: 1 – is the zone of intensive abrasive wear; 2 – is the zone of moderate intensive wear (Fig. 7).

Zone 2 is recommended to strengthen point-wise, for the formation of the saw-tooth shaped blade. As a result of the formation of such form of the cutting total the quality of technological operation improves and traction resistance decreases by 3.2…6.4 %.

As a result of the studies of the wearing process of serial V-shaped sweeps the dependence of the relation between the parameters of the local zones was determined:

$$\vartheta = \frac{\varepsilon_1 S_1}{\varepsilon_2 S_2} \quad (2)$$

where $\varepsilon_1 S_1$ – is the index of the wear resistance of the zone 1 (product of the wear resistance and thickness of the strengthening coating); where $\varepsilon_2 S_2$ – is the index of wear resistance of the zone 2.

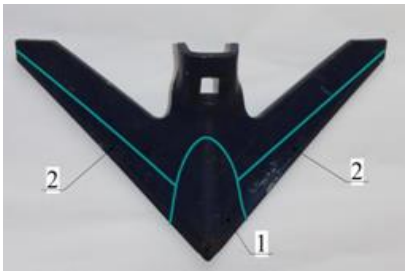


Fig. 7. Scheme of applying wear resistant coating on the working surface of the V-shaped sweep for achieving self-sharpening effect and wear equistability: 1, 2 – is the zone of intensive and moderate abrasive wear, correspondingly

Value of ϑ criterion is defined for V-shaped sweeps of various types and aggregative state (Table 5).

Table 5

Value of the relation between the parameters of wear resistive coatings of different local zones of the V-shaped sweep of the cultivator

Soil	Criterion ϑ
Sandy-loam soil	1.2 – 1.3
Sandy-loam soil (fluff soil)	1.05 – 1.15
Medium-textured loam soil	2.45 – 2.55
Medium-textured loam soil (fluff soil)	1.8 – 1.9
Light clay	2.4 –2.5
Light clay (fluff soil)	1.8 – 1.9

Character of the working parts wear can considerably change when the speed of the relative motion of the working part in the soil increases. Value of ϑ criterion is determined at the speed of the tillage machine operation within the limits of 10 – 11 km/hr. If the speed of the tillage machine increases, the correction factor must be applied:

$$\Psi = (\upsilon_{\text{роб}} - \upsilon_0) \times \beta \quad (3)$$

where $\upsilon_{\text{роб}}$ – is the speed of the tillage machine motion; υ_0 – is the speed of the tillage machine motion in the process of the operation studies for determining ϑ criterion (10 – 11 km/hr); β – is the correction factor, that takes into account the change of the tillage machine speed (Table 6).

Table 6

Value of the correction factor, that takes into account the change of the tillage machine speed

Soil	Correction factor β
Sandy-loam soil	1.03
Medium-textured loam soil	1.025
Light clay	1.012

For achieving the self-sharpening effect and provide wear equistability it is necessary to sharpen the cutting edges of the working parts of the tillage machines at sharpening angle of different values for zone 1 and 2 (Table 7).

Table 7

Needed sharpening angle of the cutting edge of V-shaped sweep for achieving self sharpening effect and wear equistability

Local zone	Sharpening angle, deg.
Nose part (zone 1)	25…30
Blade part (zone 2)	8…10

Performing the analysis of the means and methods of improvement the wear resistance of the V-shaped sweeps, the researchers did not obtained clear-cut answer regarding the side where wear

resistant covering (internal or external) should be applied, that is why, for the experimental studies V-shaped sweeps with the internal and external application of coating were manufactured.

Wear resistance of V-shaped sweeps, reinforced from the internal side turned out to be 1.6 – 1.9 times less as compared with V-shaped sweeps with the external reinforcement during operation on clay loam and sandy loam soils. This regularity is explained by braking the blade edge as a result of the «projection» of the reinforced layer over the viscous (carrying) layer. During the operation of the V-shaped sweeps with the reinforced internal surface on clay soils the growth of the wear resistance within the limits of 3% was observed, as compared with V-shaped sweeps, reinforced from the external side, also self sharpening effect was observed.

Application of the suggested methods of strengthening allowed to improve considerably the wear quistability of V-shaped sweeps of the cultivators (Figs. 8 – 10). Assessment of wear equistability was performed by the relation of the wear intensity of the local zones.

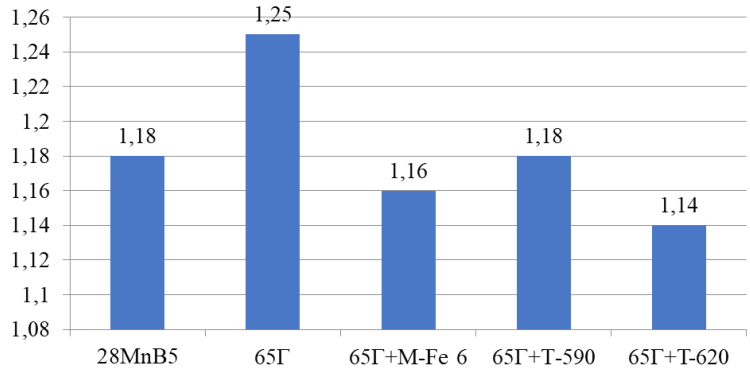


Fig. 8. Wear equistability of V-shaped sweeps in the process of operation on clay loam soils (run 10 ha per one V-shaped sweep)

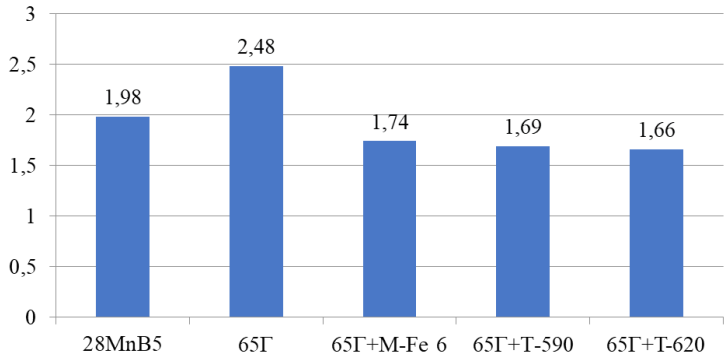


Fig. 9. Wear equistability of V-shaped sweeps in the process of operation on clay loam soils (run 10 ha per one V-shaped sweep)

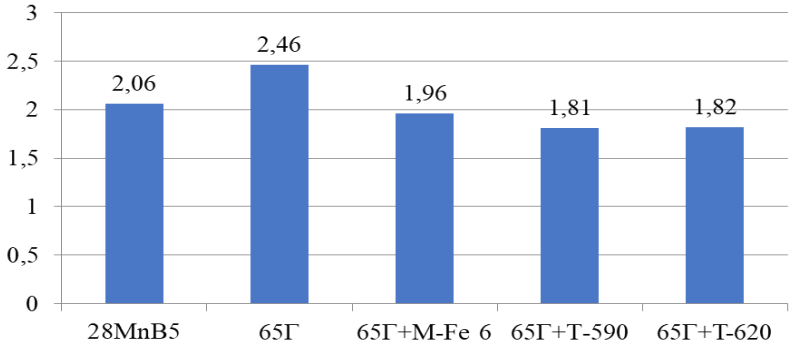


Fig. 10. Wear equistability of V-shaped sweeps in the process of operation on light clay (run 10 ha per one V-shaped sweep)

From the studies, carried out, the conclusion can be made that the application of the

strengthening technologies enables to increase wear equistabbility of V-shaped sweeps of the cultivators by 9 – 49 % and it results in maintaining the stable sharpening angle for the entire period of operation.

Conclusions

The results, obtained, enable to introduce into production process V-shaped sweeps with the provision of wear equistability and achieving self-sharpening effect, taking into account the operation modes and operation conditions.

Wear resistance of V-shaped sweeps, reinforced from the internal side turned out to be 1.6 – 1.9 times less as compared with V-shaped sweeps with the external strengthening during the operation on clay loam soils and sandy loam soils. This regularity is explained by the braking of the blade edge as a result of the «projection» of the reinforced layer above the viscous (carrying) layer. In the process of V-shaped sweeps with the reinforced internal surface operation on the clay soils the increase of wear resistance within the limits of 3 % as compare with V-shaped sweeps, reinforced from the external side and self-sharpening effect are observed.

As a result of the application of the suggested measures, the wear equistability increase on the sandy loam soils is observed within the limits of 6…9 %, on clay loam soils – 42…49 %, on light clay – 25…36 %.

Self-organization of cutting elements of the reinforced V-shaped sweeps results in reduction of the traction resistance and decrease of fuel consumption of the mobile energy facility on average by 11 %.

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