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IMPACT OF THE PRELIMINARY CORROSION ON THE INTENSITY OF THE ABRASIVE WEAR OF THE WORKING TOOLS OF THE TILLAGE MACHINE

As a result of the analysis of the state-of-art of the problem of the preliminary corrosion impact on the intensity of the abrasive wear of the working tools of the tillage machines, the factors, influencing the intensity of the abrasive wear of the working tools of the tillage machines were established and it was noted that nowadays the studies dealing with the impact of the preliminary corrosion on the intensity of the abrasive wear were carried out only in the laboratory conditions, that is why, it is necessary to carry out field studies in the working environment.

It is established in the paper that during the off-season storage of the tillage machinery the equipment is influenced by the atmospheric corrosion. The most intensive corrosion processes occur in the zone of functional contact where the traces of the abrasive wear are present. This phenomenon can be explained by the character of the abrasive wear because as a result of such type of wear the secondary structures, micro faults and faults of the crystalline lattice are formed of the surface of friction.

Atmospheric corrosion of the working tools friction surfaces of the tillage machines leads to changes of the tribomechanical characteristics, namely: reduction of microhardness by 3.54…9.6 %, and growth of wear intensity by 9.4 %. For the determination of the efficiency of the application of foreign and domestic conservation materials for the protection against atmospheric corrosion of the frictional surfaces during the off seasonal storage corresponding studies were carried out. As a result of the research it was established that for the conservation of the working tools of the tillage machines it is more expedient to use domestic conservation materials of БЕСТ КМ-1 and ПВК type as foreign analogs show identical results but their price is 2…2.5 times higher. Rational methods and means for storage and conservation of the working tools of the tillage machines to minimize the impact of the atmospheric corrosion on the frictional surfaces of the working tools are recommended.

Key words: *corrosion, abrasive wear, storage, steel, tillage machine, microhardness, working tool.*

Introduction

Atmospheric corrosion realizes extremely negative impact on various spheres of national economy (mining industry, agriculture, energy branch, transport, etc.) [1]. According to the data, presented in [2], losses of corrosion in the USA are more than one hundred million USD per year. In the agricultural sphere greater part of the machinery are subject to atmospheric corrosion. But the greatest impact corrosion exercises on the working tools, which are not protected by the covering and in the process of operation are subject to abrasive, abrasive-impact and other types of wear. As a result of wear the faults appear on such surfaces, they intensify the process of the atmospheric corrosion. Intensive flow of the atmospheric corrosion process on the surfaces of the working tools during their storage leads to the intensive wear of these surfaces after their removal from the storage. This problem is very actual for the working tools of the tillage and seeding machines as they are in storing 90 % of time and the surfaces of their working tools (shares, disks, shovels, etc.) after execution of the technological operations do not have the protective covering and have numerous faults (microcracks, vacancies, etc.). That is why, the study of the impact of the preliminary atmospheric corrosion on the intensity of the abrasive wear of the working tools of the tillage machines and search of the ways, aimed at reducing its negative impact is really important task.

Analysis of the recent studies

Profound understanding of the process of the abrasive wear of the working tools of tillage machines enables to significantly increase their wear strength. The process of the abrasive wear of the working tools of the tillage machines is of complex character as in the area of the frictional contact chemical, mechanical and physical processes take place simultaneously. The prevailing process, occurring in the course of the abrasive wear of the working tools of the tillage machines is mechanical process. Chemical and physical processes occurring in the area of frictional contact during the wearing of the working tools of the tillage machines do not influence greatly the intensity of the abrasive although produce minor impact on the total value of the abrasive wear. Chemical processes on the friction can decrease the hardness of the surface layers and accelerate the flow of the mechanical processes in the area of the frictional contact of the working tool surface and soil environment.

The process of the abrasive wear of the working tools of the tillage machines in different periods was studied by Kostetskyi B. I. [3], Kragelskyi I. V. [4], Severniov M. M. [5], Aulin V. V. [6], Borak K. V. [7] et al. By the results of the research, performed by these authors the conclusion can be made, that the process of wearing of the working tools surfaces of the tillage machines can occur by the fixed, semifixed and free abrasive particles. The degree of the abrasive particles fixing depends on the state of the soil environment.

In the research [7] the impact of the fixing degree on the intensity of working tools of the tillage machines was established. In this study it was revealed that the change of the fixing degree of the abrasive particles on section of the field can radically change the processes of the friction surface and either increase or decrease the wear intensity two times.

Soil humidity greatly influences the wear intensity. In the paper [8] the impact of soil humidity on wear intensity was determined (Fig. 1).

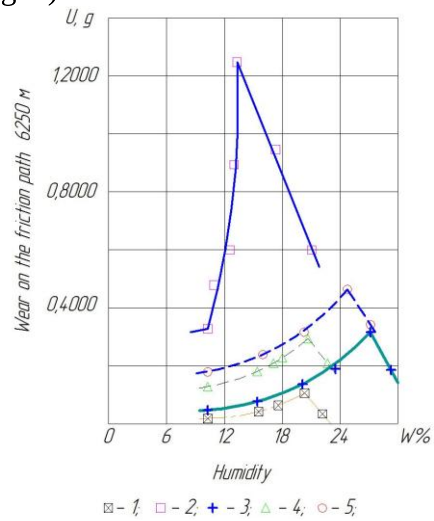

Fig. 1. Impact of soil intensity on the wear (friction route 6250 m) [8]

For all the types of the soil the increase of the wear value is observed with the increase of the soil humidity to a certain limit (critical value). After reaching the critical value on the surface of friction the formation of free moisture acting as the grease is observed, this leads to decrease of the wear intensity.

Availability of stony inclusions in the soil within the limits of 5.17…7.25 % results in the increase of wear intensity 3.1 times [10].

Phase composition of soil also influences the intensity of the working tools of the tillage machines where they operate. Soil is known to consist of four phases (Fig. 2).

Solid phase of soil is determining of its abrasive properties, as it contains mineral particles, which hardness is higher that the material of the working tools of the tillage machines.

Hardness and form of the abrasive particles of soil determines the possibility of the most negative mechanical process – microcutting. If the hardness of abrasive particles is less than 0.7 of the material of the working tool, microcutting is not observed. That is why, greater part of studies, dealing with the improvement of durability and wear resistance of the working tools of the tillage machines, are aimed at increasing hardness of the wear areas of working tools of the tillage machines.

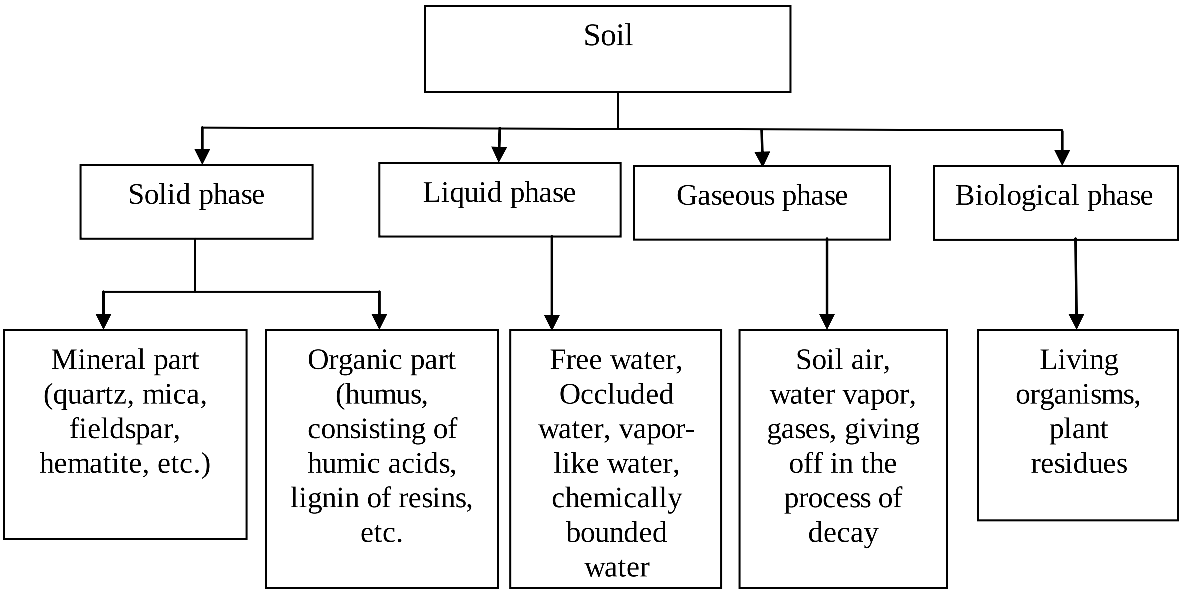

Fig. 2. Phase composition of the soil [9]

Fundamental analysis of the research regarding the impact of the abrasive particles on the wear intensity is presented in [11]. It is established that the increase of the abrasive particles size to critical size (CPS) leads to the directly proportional increase of the wear rate (Fig. 3).

At attaining of the critical size of the abrasive particles three phenomena can be observed (Fig. 3): 1 – decrease of the wear rate; 2 – stabilization of the wear rate; 3 – increase of the wear rate. Unfortunately, nowadays, generally accepted explanation of this phenomenon is missing.

It is considered that the increase of the steel hardness leads to the proportional increase of wear resistance to the abrasive wear. In modern studies this statement is in question. In the research [12] the data have been obtained which indicate the luck of the direct dependence of the wear resistance on the hardness of the friction surface and it was revealed that steel ductility influences greatly the resistance to the abrasive wear (Fig. 4).

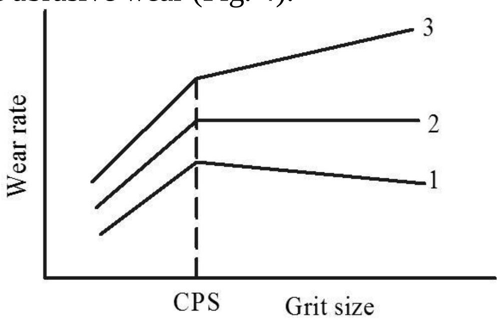

Fig. 3. Dependence of the wear rate on the size of the abrasive

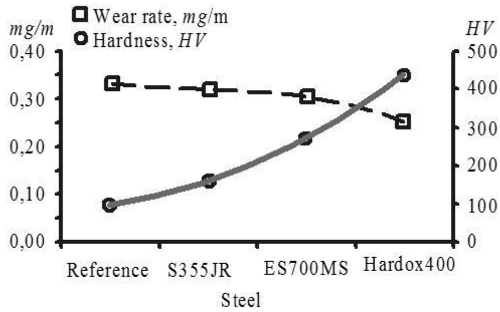

Fig. 4. Wear rate and steel hardness

It has been established that the increase of the carbon content in iron carbon alloys leads to the increase of the resistance to the abrasive wear (Fig. 5) [13, 14]. In alloy steels the determining factor of the resistance to the abrasive wear is the content of the doping elements.

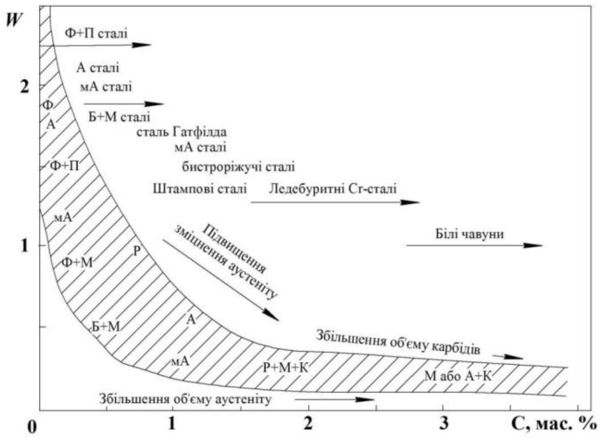

Fig. 5. Dependence of the iron carbon alloys wear on the content of the carbon [14]

It should be mentioned the impact on the abrasive wear intensity of the relative speed of displacement, angle of the abrasive attack to the friction surface, acidity of the abrasive medium, soil hardness and parameters of steel microstructure. Impact of all these factors is profoundly studied by the researchers, corresponding dependences have been established. Factors, influencing the intensity of the working tools wear and are not sufficiently investigated are preliminary corrosion of the surface during the off seasonal storage and the presence of nutritive debris in the abrasive medium.

Atmospheric corrosion causes damage to all branches of national economy of Ukraine. These damages comprise not only physical loss of metal but first of all loss of the operational state of the machines and equipment, need of their repair. The most important factors, influencing the rate of the atmospheric corrosion of the parts and working tools of the machines are: availability of the protective coating, humidity of the atmosphere, damage of the surface, duration of the contact of the surface with the atmosphere, chemical composition of the materials the parts and working tools are made of and the ambient temperature.

In agro-industrial complex simple agricultural machines (ploughs, harrows, tillers, etc.) suffer corrosion, these machines, in greater part of cases in the period of the off season storage are located in the open paved, concrete or ground yards.

First fundamental studies regarding the impact of the preliminary atmospheric corrosion on the intensity of the abrasive wear of steels were carried out in the middle of the last century by Professor Severniov M. M. Studies were performed in the laboratory conditions, for the investigation steel 65Г, steel 45 and steel 3 were used. Duration of atmosphere corrosion of the steel samples was 20 months. As a result of the studies it was established that the wear intensity after the preliminary corrosion increases 2.1…6.8 times, depending on the type of steel, method of storage and location of the samples [5].

More profound studies were carried out in Ukraine in the conditions of three soil and climate zones of Ukraine (Polisia, forest-steppe and steppe) in the period of 2014 – 2018 [7]. By the results of the studies it is established that the presence of the preliminary corrosion leads to the increase of the wear intensity of the steel samples (Fig. 6).

All the above-mentioned studies were carried out in the laboratory conditions and can not objectively describe the impact of the preliminary corrosion of the working tools of tillage machines on the intensity of their wear, that is why, it is expedient to perform operational studies in the field conditions.

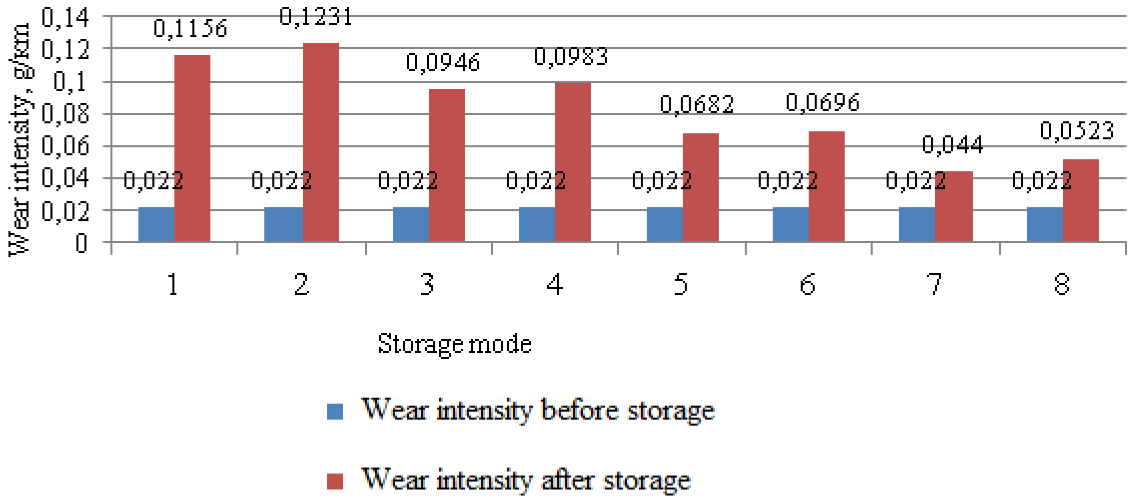

Fig. 6. Wear intensity of the steel samples, friction path – 7488 m (storage conditions: forest-steppe zone, height of samples location 500 mm above the storage surface, sample – steel 65Г with bulk tempering at the temperature 810...830 °С and medium-temperature tempering 460…480 °С): 1 – in the open space with the ground surface; 2 – in the open space with grass surface; 3 – in the open space with the concrete surface; 4 – in the open space with paved surface; 5 – under the shed with the concrete surface; 6 – under the shed with the paved surface; 7 – in the closed heated building with concrete surface; 8 – in the closed unheated building with concrete surface [7]

As a result of the analysis of the problem of the preliminary corrosion impact on the intensity of the abrasive wear of the working tools of the tillage machines, the factors influencing the intensity of the abrasive wear of the tillage machines working tools are determined, also it is established that the studies, regarding the impact of the preliminary corrosion on the intensity of the abrasive wear were carried out only in the laboratory conditions, that is why, it is necessary to perform the operation studies in the field conditions.

Technique of carrying out the researche

In the process of the research general scientific and special methods of research were used: observation, experiment, comparison, analysis, synthesis, forecasting, abstraction, graphic and correlation methods.

The program of the research provided the realization of the following stages:

– determine the intensity of the corrosion processes on the surfaces of the working tools of the tillage machines and zones of the origination and greatest affection by corrosion;

– determine the change of microhardness of the working tools surfaces of the tillage machines as a result of their damage by corrosion;

– perform operation tests of the impact of the preliminary corrosion during the off season storage on the intensity of the working tools of the tillage machines wear;

– perform operation tests of the suggested methods and means, aimed at increasing corrosion processes resistance on the friction surfaces of the working tools of the tillage machines.

Determination of the corrosion intensity on the surfaces of the working tools of the tillage machines, corrosion origination zones and zones of the greatest affection was performed, applying the method of the inspection of the machines, put on the off season storage in the conditions of LLC «Agrarian System Technologies». Inspection was carried out each 15 days (Fig. 7). Disk working tools, duck foot shovels and plowshares were examined. Materials of the working tools of the tillage machines are: steel 65Г, steel 28MnB5 and steel Hardox 500.

Fig. 7. Photo of the friction surface of the tillage machine working tool in the period of the off season storage

Determination of the microhardness of the friction surface of the tillage machines working tools was performed by means of the portable durometer Т-УД2 (Fig. 8). Measurements were performed before the off season storage and during the removal from the storage. Studies of the microhardness were performed according to ASTM A1038 [16], penetration distance of the indector is 30…50 μm.

Fig. 8. Micro durometer Т-УД2 , used for the determination of the microhardness of the friction surfaces of the tillage machines working tools

For the investigation of the impact of the means and methods of the off season storage the conservation of the friction surfaces of the tillage machines working tools was performed, using the following materials : БЕСТ КМ-1, ПВК and Shell Ensis Oil N. Storage of the tillage machines was realized on the open spaces with the concrete, paved and ground covering and under the shed with concrete and paved covering.

Wear intensity of the tillage machines working tools was determined by weighting method, using balance CP 34001 S.

Results of the research

Durability of the machines parts can be increased using three groups of methods: operational, constructional and technologic. Nowadays, greater part of the researchers pay main attention to the construction and technological methods, leaving out of consideration operational group. In authors` opinion [7] applying operational methods, wear resistance and durability of the parts of the agricultural machines can be increased three times. That is why, these methods should be paid more attention.

In autumn-winter period of 2020 – 2021 for the determination of more efficient method of tillage machines storage the inspection of the storage methods was carried out in 17 agricultural enterprises. Results of the study are presented in Fig. 9 – 11.

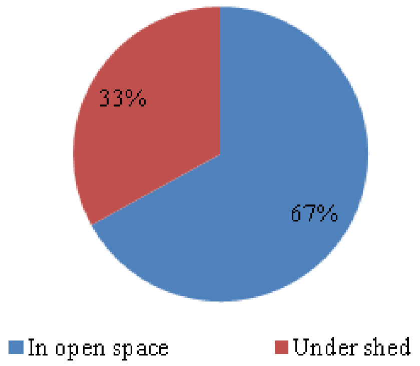

Fig. 9. Percentage distribution of the methods of tillage machinery storage according to its location

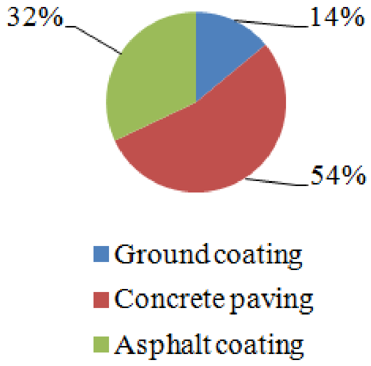

Fig. 10. Percentage distribution of the space covering, used for the off season storage of the tillage machines

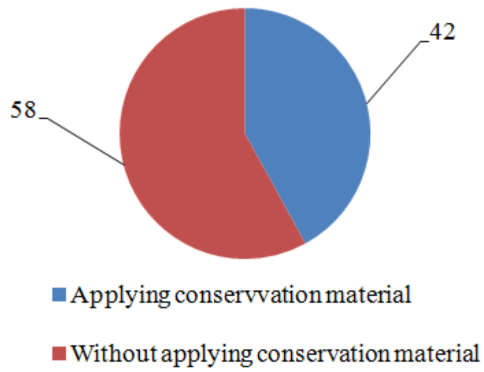

Fig. 11. Percentage distribution of the availability or absence of the conservation coating on the working tools of the tillage machines in the period of their off season storage

As it is seen from the results of the research, greater part of the tillage machinery is stored in the unfavorable conditions, this leads to the intensive process of the atmospheric corrosion. Lack of conservation covering results in rapid corrosion of the working tools friction surfaces. The most intensive corrosion process occurs in the area of friction contact, where the process of abrasive wear is very active (Fig. 12). This phenomenon can be explained by the characteristic feature of the abrasive wear, as a result of such type of wear the secondary structures, micro faults and faults of the crystal lattice are formed on the friction surface.

Fig. 12. Results of the atmospheric corrosion on the friction surfaces of tillage machines working tools during off season storage after the operation

After the inspection of 174 tillage machines while their off seasonal storage in agricultural enterprises of Zhytomyr Region the ranking of the means and methods of storage according to their impact on the intensity of the atmospheric corrosion of the tillage machines working tools (from the best to the worst) can be made : 1. Under the shed with the concrete paving of the yard with the conservation coating; 2. Under the shed with asphalt coating of the yard and applied coating; 3.

Under the shed with concrete paving ; 4. Under the shed with asphalt coating of the surface ; 5. In the open space with concrete paving and applied conservation coating; 6. In the open space with asphalt coating and applied conservation coating; 7. In the open space with unpaved area and applied conservation coating; 8. In the open space with concrete paving ; 9. In the open space with asphalt coating ; 10. In the open space with unpaved area and applied conservation coating. In numerous studies it is noted that machine parts, stored in closed heated premises with the applied conservation coating undergo corrosion impact to less extent. Unfortunately, practice shows the lack of such storage conditions in agricultural enterprises of Ukraine.

It should also be noted the importance of location of agricultural machines on the supports as their direct placement on the surface intensifies the process of atmospheric corrosion. Especially vividly this can be observed in the yards with unpaved area. In [7] the optimal height of the support for the off season storage of agricultural machines is determined, it must be at least 500 mm.

Presence of the atmospheric corrosion on the friction surfaces of the working tools of the tillage machines leads to the change of tribomechanical characteristics of this surface. As a result of the corrosion processes during five months the decrease of the microhardness of the friction surfaces by 3.54…9.6 % (Fig. 13), depending on the type of steel, used for manufacturing of this working tool took place . Hardness on the surface after the atmospheric corrosion was determined in the zones of the greatest damage without elimination of the corrosion products.

The obtained results of the microhardness change of the friction surfaces of the working tools of the tillage machines allow to state that the more qualitative is the steel, the smaller value of microhardness change is observed (Fig. 13).

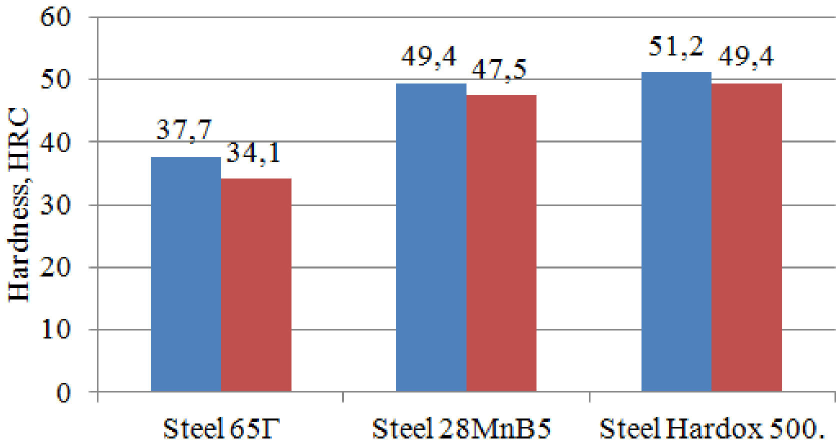

Fig. 13. Microhardness change on the friction surfaces of the working tools of the tillage machines (blue color – prior to corrosion processes, red – five months after the storage in the open space on the unpaved surface without applied conservation coating)

For the determination of the preliminary corrosion impact on the intensity of the abrasive wear the studies, using two pairs of shares, manufactured from steel 65Г were carried out: the first pair – was stored on the open spaces on the unpaved surface without applied conservation coating; the second pair was stored in closed, heated space, with the applied conservation coating.

Studies were carried out using machine-tractor unit Т-150К+ПЛН-5-35. Motion speed of the unit 7 – 9 km/hr. Soils are mid-loamy. For the trustworthiness of the results of the research, the shares were placed in chessboard order: 2-4 and 3-5. The results of the research are shown in Fig. 14.

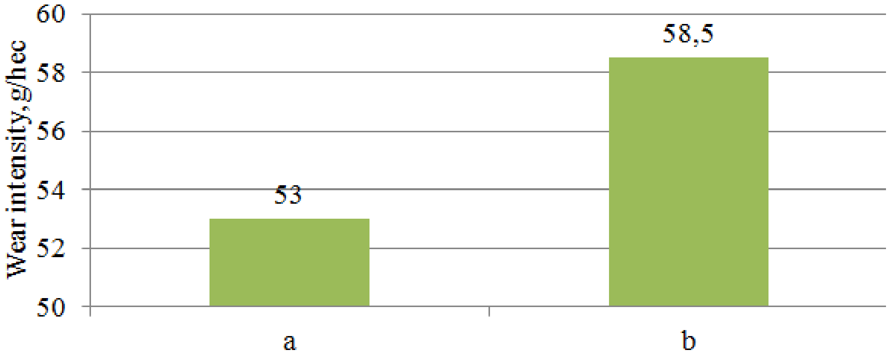

Fig. 14. Wear intensity of the plough shares, manufactured from the steel 65 and removed from the storage

Measurements were performed after plowing on the area of 5 ha, i. e., running time of one share was one hectare. Further on wear intensity became even and was the same for all the types of shares. These results testify the great impact of the preliminary corrosion of the friction surface on the intensity of the abrasive wear as the intensity of wear in shares, which were completely damaged by corrosion is higher at the initial stages of operation by 9.4 %, as compared with the shares, where the traces of corrosion were not available.

For the determination of the efficiency of domestic and foreign conservation materials, needed for the protection against atmospheric corrosion of the friction surfaces corresponding studies were performed. Disk working tools of the tillage machines were covered with conservation materials БЕСТ КМ-1, ПВК, Shell Ensis Oil N and were put for the off season storage in the most unfavorable conditions (in the open space with unpaved surface). As a result of the research it was established that considerable difference regarding the rate and intensity of the corrosion processes on the friction surfaces as a result of usage of the above-listed conservation materials was not observed. That is why, for the conservation of the working tools of the tillage machinery the domestic conservation materials of БЕСТ КМ-1 and ПВК types should be used, as the foreign analogs are 2…2.5 times more expensive.

Conclusions

In the process of the off season storage of the tillage machinery it is subjected to the impact of atmospheric corrosion. Most intensive corrosion processes occur in the zone of the friction contact, where the traces of the abrasive wear are obvious. This phenomenon can be explained by the specific nature of the abrasive wear, since as a result of such type of wear the secondary structures, micro faults and faults of the crystal lattice are formed on the friction surface.

Atmospheric corrosion of the friction surfaces of the tillage machines leads to the change of tribomechanical characteristics, namely: reduction of microhardness by 3.54…9.6 %, and increase of the wear intensity by 9.4%.

Rational means and methods of storage and conservation of the working tools of the tillage machines are recommended for the minimization of the atmospheric corrosion impact on the friction surfaces of the working tools of the tillage machines.

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