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WEAR RESISTANCE OF WORKING BODIES OF GROUND TREATMENT MACHINES STRENGTHENED BY COMPOSITE ELECTROLYTIC COATINGS

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Summary. *The results of researches of influence of composite electrolytic coverings (CEP) on abrasive wear resistance of working bodies of tillage machines: paws of cultivators, disk harrows, plowshares are resulted in work. The influence of SiC (silicon carbide) filler particle sizes and their volume content in the nickel matrix on the tribological characteristics of QES applied to steel samples 45 was studied. QES with inclusions of silicon carbide fractions 28/20 and 50/40 microns, which have the least wear at all loads. The content of filler in such coatings is, respectively, 24 and 28 vol.%. Compared with galvanic nickel, such coatings have a reduction in wear of 13 and 5 times at loads of 20, 40, 60 N, respectively. Analysis of the test results showed that with increasing load, such as the coefficient of friction decreases and with increasing SiC particle size for the range of particle sizes of the filler 40… 60 µm, the coefficient of friction is minimal. For coatings with large filler particles (fraction 100/80) the coefficient of friction is higher. Thus, tribological studies show the prospects and effectiveness of CEP to increase the wear resistance of the working bodies of tillage machines.*

Key words: *tillage machines, durability, composite electrolytic coatings.*

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Formulation of the problem. The physico-mechanical characteristics of QES based on a nickel matrix with a filler containing silicon carbide (SiC) are largely determined not only by the geometric size of SiC particles, but also by their volumetric content in the Nickel matrix. The maximum value of strength is achieved at the optimal content of particles in the coating, the excess of which sharply reduces the physical and mechanical characteristics of CEP. Therefore, the aim of this work is to find the optimal ratio between the particle size of silicon carbide and their volume content in the nickel matrix to ensure maximum strength and wear resistance of the working bodies of tillage machines.

Analysis of recent research and publications. Numerous studies indicate that there are different approaches to solving this problem. Thus, in [1] the issues of strengthening the blades of tillage working bodies of agricultural machines with the formation of the effect of self-sharpening are considered, and in [2] there are constructive, operational and technological ways to increase the wear resistance of working bodies of tillage machines. Technological methods include, first of all, selection of materials and heat treatment, which provide high wear resistance in the conditions of abrasive wear [1, 2]. In [3] it was shown that the use of optimal nitriding regimes in anhydrous glow discharge allowed to increase the wear resistance of the cultivator legs by 1.7… 1.8 times. The author of [4] recommended the following materials for the manufacture of parts that work in abrasive environments: manganese steels (30Г, 50Г, 65Г, 110G6H3L), chromium alloy steels (38ХА, 40Х, 45Х, Х12, Х12Ф1, Х6ВФ), multicomponent alloys steels and alloys (12ХН3А, 17ХГ2СФР, 08Х18Н10Т), hard sintered alloys (ВК6, ВК8, ВК15, ВК20). Technical requirements for disks to domestic equipment include their manufacture of steel 65G, or its substitute – steel

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M76 and steel 45 with heat treatment to a hardness of 39… 44 HRC. Disks from foreign manufacturers are made of more durable steels, including Bellota wheels – 28MnB5 steel, Case – Earth Metal steel. The cost of such disks is 2.0… 2.3 times higher than the cost of domestic disks and has 20… 30% higher wear resistance [2]. The use of quality metals and alloys is not economically feasible, so the way out should be sought in the methods used for surface hardening of work surfaces. At present, in Ukraine serial working bodies of tillage machines are made of steels 65Г, 45 and L53, which in hardened state (hardness 37… 43HPC) have satisfactory indicators of relative elongation but a small strength limit ($\sigma_в$ = 880…1080MPa). According to many years of research and analysis of the results of operational tests of tillage machines, only in the first year of operation due to breakage (or deformation followed by breakage) fail about 40% of plowshares and 15% of shelves, 20% of cultivator legs and 30% of different types disk working bodies [1]. In general, it can be stated that for most regions of Ukraine one set of parts of working bodies of tillage machines is not enough for the current annual cycle (spring + autumn), and therefore it is necessary to continue searching for new, economically sound methods and ways of surface strengthening of working bodies of tillage machines.

Forming the goals of the article. The purpose of the study is to develop a technology for strengthening the working bodies of tillage machines by applying composite electrolytic coatings (CEP).

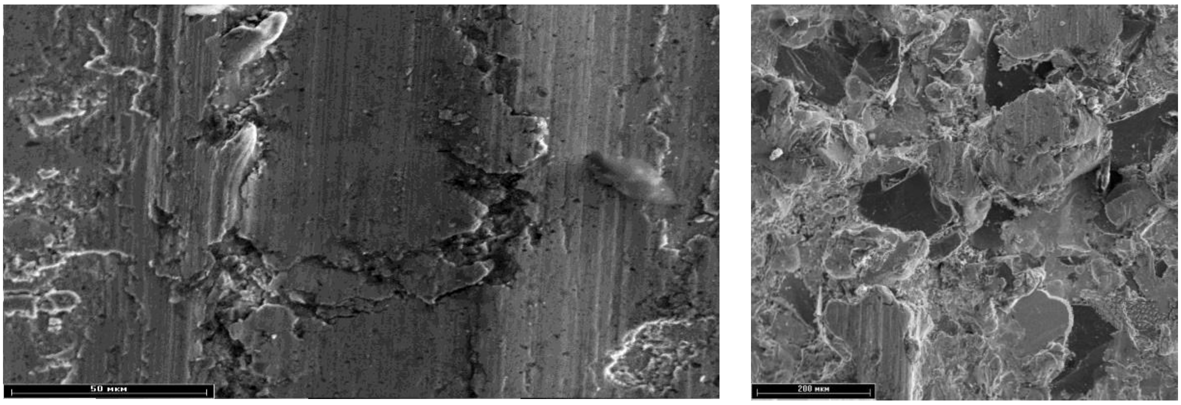
Presentation of the main material of the study. Nickel-based coatings with SiC particles of different fractions are used in the work and for convenience we will denote the coatings by the size of the filler particles. For example, nickel CEP with SiC particles fraction 5/10 μm is denoted as Ni + SiC5, fraction 28/20 μm as Ni + SiC28, 50/40 μm – Ni + SiC50, 100/80 – Ni + SiC100, and coatings with nanoparticles size about 50 nm – Ni + SiCnano. Amorphous boron powders with a dispersion of about 1 μm were also used in the work. The formation of CEP with Ni-SiCnano and Ni-SiC5, as well as with inclusions of amorphous boron was performed on a vertical cathode with continuous stirring of the suspension in our installation [5]. The formation of CEP with particles SiC28, SiC50, SiC100 with the addition of amorphous boron powders was carried out on a horizontal cathode. Thus, nickel-based coatings with SiC particles of different fractions are used in the work and for convenience we will denote coatings by the size of the filler particles. For example, nickel CEP with SiC particles fraction 5/10 μm is denoted as Ni + SiC5, fraction 28/20 μm as Ni + SiC28, 50/40 μm – Ni + SiC50, 100/80 – Ni + SiC100, and coatings with nanoparticles size about 50 nm – Ni + SiCnano. Amorphous boron powders with a dispersion of about 1 μm were also used in the work. The number of boron and silicon particles in the coating was determined by chemical and metallographic analyzes. The bulk content of the filler particles depends on the geometric dimensions of the particles. The CEPs formed by us contained a maximum of 8% vol. for SiCnano and up to 13% vol. for SiC5. The M22-M friction machine was used to study the antifriction properties of composite coatings, which allows to automatically register the main characteristics of friction and wear processes (linear steam wear and friction coefficient) without removing the sample from the machine. 40 mm diameter rollers made of hardened steel 45 (HRC 45–48) were used as a counterweight. At a distance of 0.5 mm from the friction surface, a chromel-copel thermocouple was introduced into the sample, which allows to control the change of temperature in the friction zone and to judge the stabilization of friction and wear processes. Tests of samples with coatings were performed under friction conditions without lubrication according to the shaft-plane scheme, the friction load was P = 20; 40; 60; 150 N, sliding speed V = 0.5 m/s. Friction path L = 1 km. Studies have shown that the particle size of the filler has a significant effect on the wear resistance of the coating. The results of friction tests are shown in table 1:

Table 1

Wear resistance of CE-Ni-SiC depending on the size of the filler

Eye material	Load P, (N)	Coefficient of frictio, f	Weight wear of the sample I_1, (mg/км)	Weight wear of the counterbody I_2, (mg/км)	Total wear	Linear friction pair wear I, (mm/км)	Sample temperature T °C
Steel 45	20	1,3	75,7	34,6	110,3	72	48
	40	0,91	84,8	24,5	109,3	82	61
	60	0,75	82,5	26,4	108,9	76	75
Ni	20	1,3	34,6	4,5	38,1	53	43
	40	0,97	40,1	5,3	45,4	58	65
	60	0,82	45,8	7,8	53,6	64	87
$Ni+SiC_{100}$	20	1,1	59,7	37	96,7	59	44
	40	0,82	73,2	42,5	115,7	105	63
	60	0,66	81,7	54,1	135,8	118	83
$Ni+SiC_{50}$	20	0,75	2,7	4,5	7,2	10	33
	40	0,68	4,5	9,4	13,9	22	52
	60	0,61	9,2	10,6	19,8	27	78
$Ni+SiC_{28}$	20	1,1	2,6	4,7	7,3	11	43
	40	0,9	4,4	10,2	14,6	22	55
	60	0,73	9,0	12,4	21,4	26	74
$Ni+SiC_5$	20	1,3	27,7	1,8	29,5	42	48
	40	0,96	34,2	2,5	36,7	48	62
	60	0,69	38,7	8,9	47,6	53	70
$Ni+SiC_{nano}$	20	1,3	32,4	5,0	37,4	47	45
	40	0,94	33,9	5,4	39,3	48	56
	60	0,7	36,6	6,8	43,4	55	67

According to the results of experiments (Table 1), the greatest wear at these loads have steel samples without coating. In this case, significant weight wear of both the sample and the counterbody. When applying a layer of galvanic nickel with a hardness of $H\mu$ = 2.4–2.7 GPa, the weight wear of the sample is reduced by more than 2 times, and the wear of the counterbody is reduced by 4–7 times compared to the tests of steel samples without coatings. The wear resistance of CEP samples containing SiC filler of different fractions is higher than that of pure nickel coatings and it is in order to increase the wear resistance of the coating are added various solid particles. The improvement in wear resistance is explained by the increase in the mechanical properties of coatings with the addition of high-strength SiC particles (Hμ = 28–35 GPa) and the higher bearing capacity of such coatings. According to the test results, for samples with inclusions of 100/80 μm fraction, significant weight and linear wear is observed, which even exceeds the wear of the sample without coating. The hardness of the matrix increased slightly and is Hμ = 2.8–3.0 GPa, ie increased by 10–15% compared to pure Nickel due to the compositional strengthening and higher stresses in the matrix. The high wear can be explained as follows: first, the particle size is comparable to the coating thickness (200–300 μm) and under these conditions the plastic Nickel matrix cannot compensate for high contact loads on individual large SiC particles, leading to their brittle destruction and chipping. Second, the volume content of particles in the coating is the highest compared to other test samples and is 46%. Such a carbide content in the matrix will cause significant stresses that the plastic matrix cannot effectively compensate. This will lead to the fact that under the action of the load it will be destroyed and large particles, chipping, will act as abrasive particles, and thus intensify the wear process. As the load increases, the internal stresses increase even more, the matrix collapses and the particles are torn out of the coating and carried out together with the wear products or charged in the counterbody, which is confirmed by weight wear greater than linear and images of friction surfaces. On the friction surface (Fig. 2, a) there are traces of abrasive wear by free particles of filler, or fixed (caricatured in the surface of the counterbody), furrows are formed. In another photograph (Fig. 2, b) there are traces of chipping of solid inclusions from the matrix.



a b

Figure 1. Topographies of friction surfaces of Ni + SiC100 CEP: a – × 500; b – × 100

Large weight wear of the sample is observed when used as a filler for CEP small particles fraction less than 5 μm and nanoparticles 50 nm. The use of such particles slightly increases the wear resistance of the coating compared to galvanic nickel, but not significantly (reduction of sample weight loss is 10–20%), because, first, the content of SiC5 and SiCano particles is 8 and 3 vol.%, Respectively, that is, it is smaller than larger particles, and secondly, such particles more effectively strengthen the matrix (there is a dispersion hardening) than increase wear resistance compared to larger particles. This is due to the fact that in such compositions the particle size is smaller than the size of single contact spots, they can not effectively absorb the load, and therefore the main contribution to wear resistance is Ni matrix, which has low hardness and, accordingly, wear resistance. That is why the wear resistance of CEP with microparticles is almost the same as that of galvanic nickel. CEP with inclusions of fractions 28/20 and 50/40 μm have the highest wear resistance among the given coatings, they have the lowest wear at all loads. The filler content in such coatings is, respectively, 24 and 28 vol.%. At the same time coatings with inclusions of fraction of 28/20 microns have a little less wear. The weight wear of such samples is an order of magnitude less than for coatings with smaller and larger particles. Compared to galvanic nickel, such coatings have a reduction of wear by 13 – and 5 times at loads of 20, 40, 60 N, respectively. The decrease in the difference in wear resistance can be explained by the fact that with increasing load, large particles can crack, and act as an abrasive, increasing the wear of such a coating. The linear wear of the friction pair is also the smallest, but the difference in wear resistance among other coatings will be slightly smaller and is 5–2.7 times compared to galvanic nickel. For compositions with optimal particle sizes (28 μm) there are no processes of setting, abrasive and brittle fracture, there is a normal mechanical-oxidative wear process.

Conclusions. The optimal particle size of the filler SiC in the Nickel matrix from the standpoint of maximum wear resistance are particles of the fraction 28/20 μm. The lowest wear of samples with coatings is observed for the content of filler particles in the matrix of 20–25 vol.%. 3. Among the investigated coatings, other things being equal, coatings with a volume fraction of 28/20 μm fraction of about 24% have the lowest friction pair wear.

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ЗНОСОСТІЙКІСТЬ РОБОЧИХ ОРГАНІВ ГРУНТООБРОБНИХ МАШИН, ЗМІЦНЕНИХ КОМПОЗИЦІЙНИМИ ЕЛЕКТРОЛІТИЧНИМИ ПОКРИТТЯМИ

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Резюме. *Наведено результати досліджень впливу композиційних електролітичних покриттів (КЕП) на абразивну зносостійкість робочих органів ґрунтообробних машин: лап культиваторів, дискових борін, лемешів. Досліджено вплив розмірів частинок наповнювача SiC (карбіду кремнію) та їх об'ємного вмісту в нікелевій матриці на трибологічні характеристики КЕП, нанесених на зразки зі сталі 45. Найвищу зносостійкість серед наведених покриттів мають КЕП із включеннями фракцій карбіду кремнію 28/20 та 50/40 мкм, які мають найменший знос при всіх навантаженнях. Уміст наповнювача в таких покриттях складає, відповідно, 24 та 28 об.%. У порівнянні з гальванічним нікелем такі покриття мають зменшення зносу у 13 та 5 разів при навантаженнях 20, 40, 60 Н. Аналіз результатів випробувань показав, що зі збільшенням навантаження на зразок коефіцієнт тертя зменшується й зі зростанням розмірів частинок SiC для діапазону розмірів частинок наповнювача 40…60 мкм коефіцієнт тертя є мінімальним. Для покриттів з більшими частинками наповнювача (фракція 100/80) коефіцієнт тертя є більшим. Отже, трибологічні дослідження показують перспективність і ефективність застосування КЕП для підвищення зносостійкості робочих органів ґрунтообробних машин.*

Ключові слова: *ґрунтообробні машини, зміцнення, композиційні електролітичні покриття.*

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