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GALVANOPOWDER WEAR RESISTANCE COMPOSITE COATING ON FERUM GRUP METALS BASED

Composite electrolytic coatings (CEC) of the compositions Ni+B and Ni+B+Cr_3C_2 were subjected to heat treatment in vacuum as well as treatment with laser, which markedly improved their tribotechnical properties. The wear resistance increased with increasing friction loads. When the coatings were melted in vacuum, their wear resistance decreased by an order of magnitude for the Ni+B coatings and by twice for Ni+B+ Cr_3C_2 coatings, whereas upon melting with laser by 7-21 times. This is due to the presence of inclusions of the Ni_3B boride and the Ni-B-Cr-C eutectic, characterized by high mechanical properties.

Keywords: *Composite electrolytic coatings, wear resistance, heat treatment, treatment with laser.*

Analysis of the last investigations and publications. The Cr_3C_2 particles markedly increase the wear resistance of melted CEC thanks to additional strengthening of the Ni matrix with Cr carbon and dispersed graphite inclusions. The Ni+B+ Cr_3C_2 coatings have a higher wear resistance compared to that of CEC from Ni+B [1; 2]. The tribotechnical characteristics of coatings treated with laser are better than those of coatings melted in the furnace owing to the formation of a more disperse structure of the components having high mechanical properties. A discrete melting provides higher wear resistance compared to that in the case of a continuous melting. Herein coatings melted under an impulse regime possess a higher wear resistance than coatings melted by stripes. In the viewpoint of minimal wear, the optimal melted area is equal to 40% for the stripes, and to 25% for the impulse regime [3]

As a result of heat treatment in coverage of Ni-B (the eutectic of Ni-Ni_3B appears at 1080 ºC) in a kind hard framework a soft constituent is located in the intervals of which (a solid mix of boron is in a nickel) [4]. Next to a grainy granular – stratified eutectic there is an eutectic which is crystallisable in the type of dendrite with a well visible barrel and axes of first-order [5]. A well-educated eutectic has a micro hardness of H_μ=6–7 GPa, plastic constituent of coverage – H_μ=2–3,5 GPa.

Heat treatment of CEC Ni-B considerably improves them property. So dense smooth coverage CEC is characterized high wear resistant which higher in 1,4–1,8 times than initial CEC Ni-Cr_3C_2. Tearing down of counterbody is some increased thus, but not substantially. Estimating the state of surface of friction, it is possible to mark that takes a place normal mechanical oxidizing process of wear, although there are grasping tracks in some place.

Formulation of the aim. With the purpose of increase of operating properties, in a number to wear resistance, CEC add heat treatment with the change of the structurally phase state. The analysis of diagram of the state of Ni-Cr_3C_2 to show that at heat treatment to 1000 ºC recrystallizing of matrix and partial diffusion of components, diminishing of remaining tensions will take a place in CEC Ni-Cr_3C_2 only. It is consequently necessary additionally to enter in CEC particles which are able actively to co-operate with a nickel matrix. To that end multi component CEC were created by the way of besieging with a nickel simultaneously two types of dispersible particles: to the carbide of chrome and amorphous boron, which at heat treatment co-operate with a nickel matrix and to form with it in obedience to the diagram of the state of Ni-B of boron of Ni_3B and eutectic of Ni-Ni_3B.

Presentation of the scientific results. At besieging of CEC with two types of powders there were certain difficulties, as well as at besieging particles of Cr_3C_2 by the size of 28 mcm and nano particles of boron amorphous (a size is from 50 nm to 0,5 mcm). At over coating after the ordinary modes it was succeeded to besiege considerably less of micron particles of $(Cr_3C_2)_{28}$ (in future in CEC of particle of Cr_3C_2 will apply a size only 28/20 mcm that is why in denotation of Cr_3C_2, index 28, which live out as a rule). So for at settlement of these components maintenance of boron did not almost change (diminished from 10,5 vol.% at his separate besieging to 10,3 vol.%) information of chemical analysis, and maintenance of Cr_3C_2 made only 0,5 vol.%. Picking up the proper mode of causing attained refilling in coverage of particles of $(Cr_3C_2)_{28}$ in an amount to 20 vol.%. The structure of CEC Ni+20% Cr_3C_2+3,5%B in the initial state (without heat treatment) is resulted on fig 1, on which large particles is including of Cr_3C_2 by the size of 28 mcm, and shallow is including of boron [6].

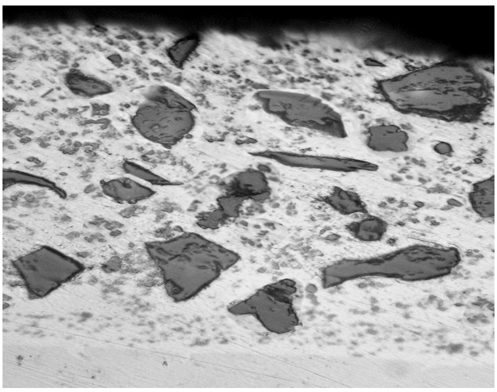

Fig 1. Microstructure of coverage of Ni+ Cr_3C_2+B in the initial state (without heat treatment), ×400

At entered particles of the coniferous forest in a nickel matrix its micro hardness some rises to $H\mu$=3,0–3,6 GPa. Thus CEC have a greater micro hardness in which except for the particles of the coniferous forest the particles of Cr3C2 $H\mu$=22–35 GPa are present yet [7].

Test on a friction and tearing down conducted on standards with including of Cr_3C_2 and B in the initial state (without heat treatment) and after a vacuum annealing at the temperature of formation of eutectic. Results of tests of nickel CEC from Cr_3C_2 are in resulted in a table 1.

The least wear resistant and most coefficient of friction among this coverage are characterizing CEC Ni-B, here is the large tearing down of both standard and counter-body. However, unlike other coverage, tearing down of standard some diminishes with the increase of loading though remains comparatively large.

At adding to composition of Ni-B of particles of Cr_3C_2 the 28 mcm wear resistant considerably raises a size (3-12 times). The approximately the same wear resistant is characterize CEC Ni-Cr_3C_2. That particles of the coniferous forest in coverage of the system of Ni-Cr_3C_2 not have considerable influence on the increase of wear resistant, but at the increase of loading even something is worsened it. It can be explained that such particles are the additional reflector-absorbers of tensions with which destruction of coverage can be begun at the high loadings.

Table 1

Results of tests of nickel CEC from Cr_3C^2 and B

Coverage	Loading of P (N)	Coefficient of friction, *f*	Gravimetric tearing down of sample (mg/km.)	Gravimetric tearing down of counterbody (mg/km)	Linear tearing down of pair of friction of I (mcm/km)
Ni-B without melting	20	1,2	38,3	12,3	50
	40	0,94	31,4	10,6	40
	60	0,8	29,9	11,5	35
$Ni-Cr_3C_2$	20	1,1	2,6	4,7	11
	40	0,9	4,4	10,2	22
	60	0,73	9,0	12,4	26
$Ni-Cr_3C_2-B$ without melting	20	0,96	2,5	4,0	9
	40	0,9	4,5	8,2	21
	60	0,8	11,3	14,9	30
Ni-B melting is in a vacuum	20	1,05	1,9	5,1	10
	60	0,85	4,9	13,0	19
	150	0,63	8,3	14,8	26
$Ni-Cr_3C_2-B$ melting is in a vacuum	20	1,1	1,8	5,4	10
	60	0,6	4,3	13,5	17
	15	0,58	6,7	15,2	23

At melting of coverage of Ni- Cr_3C_2-B positive influence of particles of Cr_3C_2 is set, inert to the nickel matrix at thermal treatments, there are tribotecnical properties on their. So the wear resistant grew in 1,5–2,1 time comparatively with not melting coverage of Ni- Cr_3C_2-B (Ni- Cr_3C_2), and 1,25 time comparatively with melting coverage of Ni-B without the particles of Cr_3C_2. It is marked also, that these coverage had the least coefficient of friction among the tested coverage.

Results heat treatment of CEC is by the concentrated energy sources. The necessity of application of vacuum at heat treatment of CEC is related to considerable technological difficulties (in the case of heating of details of largeness, at a necessity the local strengthening of surface of details and other). In addition, at such type of heat treatment a detail and coverage which sometimes results in undesirable structural changes in basic material of detail is heated. Heating of all of volume of detail is increased by the expense of electric power and duration of process. Therefore the expedient use for heat treatment of CEC of the concentrated energy sources. Also presents scientific interest of question in relation to forming of discrete structure at treatment the laser of CEC and finding out of influence of such treatment on wear resistant of coverage.

It was marked in a section 3, that higher mechanical properties are characterize coverage in which a strengthening phase has a pillar similar structure with a location these pillar similar educations athwart to the surface in compared to including of spherical form and during the orientation of pillar similar educations parallel of surface. In practice such model can be realized at treatment of coverage by a laser both on micro- and on a macro level. On a micro level due to high speeds of heating and cooling have the directed crystallization of eutectic of Ni-Ni3B from basis to the surface, which is crystallizable as dendrite in which the axes of the second order do not have time to appear through high speed of cooling, and as a result get the structures of pillar similar structure. Composition of coverage of Ni-B is near to the eutectic (the alloy of eutectic composition has 4 mas.% (11,5 at.%) a boron). Through high speeds of cooling surplus primary crystals do not have time to grow and a eutectic which promotes to yet greater grinding down of phases turns out. Thus an eutectic is got at treatment a laser has considerably higher hardness of H_{μ}=10–12 GPa (placed 15 GPa) than eutectic is got at the stove heating of H_{μ}=6,4–7,2. It is explained more dispersible structure and greater amount of borons in an eutectic. Also there is a transitional layer between melting and meltingless areas a micro hardness in which changes from 10 GPa to 3-4 GPa (a micro hardness of CEC is in the initial state).

On a macro level this model will be realized at discrete spot-treatment of coverage for help a laser. At focusing of bunch to the laser on-the-spot with melting on the depth of coverage it is possible to get un dimensional, or two measurements pillar similar structure. Thus melting of standards was conducted with the different area of melting, which was estimated the amount of melting bars or small holes.

For tests on a friction and wear the standards of CEC were selected will make Ni-B and Ni-Cr_3C_2-B with the different area of melting. At melting bars took away standards without melting, fully melting and melting discretely treated with an area 60, 40 and 20%. At melting points took away the discretely treated standards with the area of melting 15, 25 and 45%.

The results of tests on a friction and wear for CEC Ni+B are resulted in a table 2, for CEC Ni+Cr_3C_2+B – in a table 3.

As a result of tests evidently, that during the lead through of superficial heat treatment substantially influences on wear resistant of standard with coverage area of melting. It is possible to mark the following:

– Coverage of composition of Ni+B+Cr_3C_2 has higher wear resistant than CEC will make Ni+B. So at melting of concentrated energy coverage of composition of Ni+B+Cr_3C_2 have tearing down in 1,2–1,5 times more small; at melting in a vacuum – only in 1,1 time;

– Complete melting the wear resistant rises substantially, thus at the greater loadings this increase is more substantial, it can be explained, that such coverage anymore effectively perceive loading and have the higher bearing ability;

– Standards melting by the concentrated energy sources have an increase of wear resistant to 25% for coverage of Ni+B and to 65% for coverage of Ni+B+Cr_3C_2, in comparing to heat treatment at the stove heating in a vacuum.

If to analyze as the wear resistant of coverage depends depending on the area of melting it is possible to say, that for both types of coverage (Ni+B and Ni+B+Cr_3C_2) there is such correlation of areas melting to meltingless which the least tearing down of standard is for. Thus the wear resistant is more effectively increased for coverage of composition of Ni+B. It takes a place because coverage of composition of Ni+B+Cr_3C_2 have the considerably less tearing down, so as a strengthening phase of

Cr_3C_2 is already present in them, and melting conduces coverage to the additional strengthening.

Table 2

Results of tests on a friction and wear of CEC Ni+B after heat treatment

Variant of heat treatment of coverage		Loading of P (N)	Coefficient of friction, *f*	Gravimetric tearing down of sample (mg/km.)	Gravimetric tearing down of counterbody (mg/km.)	Total gravimetric tearing down (mg/km.)	Linear tearing down of pair of friction of I (mcm/km)	Temperature, °C
without heat treatment		2	1,2	38,3	12,3	50,6	50	47
		6	0,8	29,9	11,5	41,4	35	76
melting by bars	20%	2	0,39	2,7	1,4	4,1	18	31
		6	0,6	5,6	6,7	12,3	39	85
	40%	2	0,35	1,4	3,2	4,6	16	35
		6	0,54	3,2	7,9	11,1	36	83
	60%	2	0,38	1,6	4,1	5,7	16	32
		6	0,56	3,8	9,3	13,1	41	78
melting points	15%	2	0,89	2,5	3,1	5,6	12	35
		6	0,58	5,2	4,8	10	25	68
	25%	2	0,86	0,6	4,5	5,1	8	30
		6	0,35	1,8	7,3	9,1	24	60
	45%	2	1,1	1,6	8,4	10	27	31
		6	0,86	3,9	12,9	16,8	35	63
100%-melting concentrated by energy		2	0,39	1,8	8,8	10,6	31	32
		6	0,56	4,0	11,6	15,6	38	90
100%-melting is in a vacuum		2	1,05	1,9	5,1	7	10	42
		6	0,85	4,9	13,0	17,9	19	67

It is also possible to mark that better work on tearing down coverage which melting in the pulse-mode points than coverage melting bars are discretely treated, that coverage which have pillar similar structure.

Optimum from the point of view the minimum tearing down for coverage melting bars is an area 40%, and for coverage melting in the pulse-mode it is 25% both for coverage of Ni+B and for $Ni+B+Cr_3C_2$. So diminishing of tearing down at optimum areas for coverage melting by bars in comparing to fully melting of the concentrated sources is 1,25–1,3 times coverage times for coverage of composition of Ni+B and 1,2–1,25 for coverage of composition of $Ni+B+Cr_3C_2$, and for coverage melting in the pulse-mode is 2,2–3 times and 1,8–3,5 times, accordingly.

At the area of melting to less than, than optimum, tearing down considerably grows and at the small areas of melting (less than 20%) after the size exceeds tearing down for fully melting coverage.

Table 3

Results of tests on a friction and wear of CEC Ni+B+Cr3C2 after heat treatment

Variant of heat treatment of coverage		Loading of P (N)	Coefficient of friction, *f*	Gravimetric tearing down of sample (mg/km.)	Gravimetric tearing down of counterbody (mg/km.)	Total gravimetric tearing down (mg/km.)	Linear tearing down of pair of friction of I (mcm/km)	Temperature, °C
without heat treatment		2	0,96	2,5	4,0	6,5	9	34
		6	0,8	11,3	14,9	26,2	40	80
melting by bars	20%	2	0,39	1,6	2,3	3,9	10	31
		6	0,61	3,5	6,3	9,8	31	79
	40%	2	0,36	1,2	4,1	5,3	14	30
		6	0,6	2,2	7,8	10	25	88
	60%	2	0,41	1,4	5,7	7,1	18	35
		6	0,54	2,5	8,3	10,8	31	97
melting points	15%	2	0,92	1,3	2,8	4,1	11	38
		6	0,81	4,2	5,1	9,3	27	73
	25%	2	0,85	0,4	2,7	3,1	10	27
		6	0,80	1,5	5,7	7,2	23	73
	45%	2	0,95	0,6	5,2	5,8	14	34
		6	0,83	2,7	12,7	15,4	29	63
100%-melting the concentrated energy		2	0,39	1,5	7,4	8,9	28	34
		6	0,46	2,6	9,2	11,8	33	86
100%-melting is in a vacuum		2	1,1	1,8	5,4	7,2	10	45
		6	0,6	4,3	13,5	17,8	17	71

To explain that discretely-melting coverage have the best wear resistant than fully melting it is possible that we get composition material in which the best method plastic properties of coverage in the initial state and high hardness and wear resistant of the structures got at heat treatment are united, – eutectics, borons. So at complete melting through high hardness and fragility of coverage in him there can be cracks as a result of action of forces of superficial drew on in in the moment of crystallization from the liquid state of molten area of coverage. For coverage without melting a soft and plastic matrix can not effectively perceive loading and that is why will collapse, these can explain that at the greater values of loading the wear resistant grows more substantially for discretely melting coverage in comparing to fully melting and not melting.

In relation to tearing down of counterbody at a friction with the heated coverage it is possible to say, that most to wear down a counterbody coverage will fully melting, thus anymore a counterbody wears out in a pair with a standard to melting in a vacuum. It can be explained that in a pair with such standard a coefficient of friction will be considerably higher and the processes of fight are possible, what is not observed for the standards of the melting concentrated sources of energy.

With diminishing of area of melting of standards tearing down of counterbody will diminish and the least he will be at the minimum area of melting. So at the tests of coverage meltingless and fully melting tearing down of counterbody will be approximately equal and is considerably anymore than for discretely melting coverage. It also can be explained a high coefficient friction and on tracks a fight on-the-spot of friction (Fig. 2).

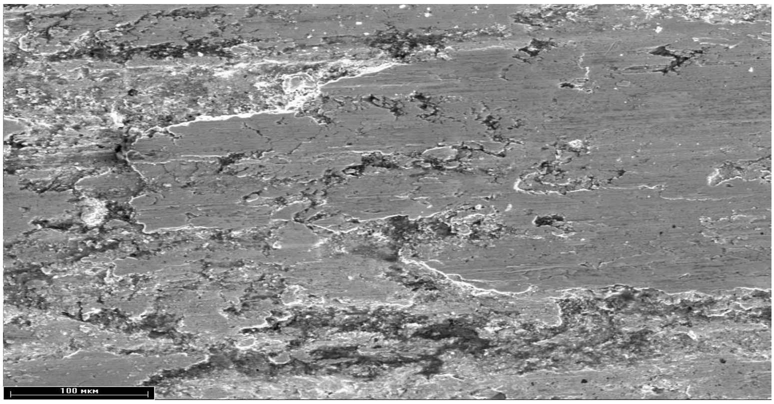

Fig. 2. Topography of surface of friction of CEC Ni+B+CR_3C_2 melting, is in a vacuum, ×200

It is also possible to mark that for melting points coverage, tearing down of counterbody will be greater. It is explained that a surface will have more grain surface with hard melting areas which will more intensively wear down a counterbody.

From the results swims out, that estimating the total tearing down it is possible to say, that discretely-melting coverage have substantially the less tearing down in comparing to coverage with complete melting. The optimum area of melting for coverage melting in the pulse-mode makes also 25%, but difference of tearing down for different areas of melting already not such substantial. For coverage melting an optimum is displaced bars diminishing of area of melting and is 20%. Thus less than is and difference between tearing down of coverage melting by bars and in the pulse-mode. So diminishing of tearing down at optimum areas for coverage melting by bars in comparing to fully melting of the concentrated sources is 1,4–2,3 energy coverage times for coverage of composition of Ni+B and 1,2–1,7 for coverage of composition of Ni+B+Cr_3C_2, and for coverage melting in the pulse-mode is 1,7–2,1 points and 1,6–2,9 times, accordingly. That in comparing to the total tearing down of fully melting coverage a difference was increased between coverage by discretely melting bars and diminished for coverage melting in the pulse-mode. Reason of it is that with diminishing of area of melting tearing down of counterbody diminishes and that coverage melting in the pulse-mode anymore wears down a counterbody than coverage melting bars. Coming from it, it is possible to recommend, that in a pair with such the coverage were use more wear resistant materials for the sake of diminishing of the total tearing down.

Conclusions. Composite electrolytic coatings (CEC) of the compositions Ni+B and Ni+B+Cr_3C_2 were subjected to heat treatment in vacuum as well as treatment with laser, which markedly improved their tribotechnical properties. The wear resistance increased with increasing friction loads. When the coatings were melted in vacuum, their wear resistance decreased by an order of magnitude for the Ni+B coatings and by twice Ni+B+ Cr_3C_2 coatings, whereas upon melting with laser by 7–21 times. This is due to the presence of inclusions of the Ni_3B boride and the Ni-B-Cr-C eutectic, characterized by high mechanical properties.

The Cr_3C_2 particles markedly increase the wear resistance of melted CEC thanks to additional strengthening of the Ni matrix with Cr and dispersed graphite inclusions. The Ni+B+Cr_3C_2 coatings have a higher wear resistance compared to that of CEC from Ni+B. The tribotechnical characteristics of coatings treated with laser are better than those of coatings melted in the furnace owing to the formation of a more disperse structure of the components having high mechanical properties. A discrete melting provides higher wear resistance compared to that in the case of a continuous melting. Herein coatings melted under an impulse regime possess a higher wear resistance than coatings melted by stripes. In the viewpoint of a minimal wear, the optimal melted area is equal to 40 % for the stripes and to 25 % for the impulse regime.

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ЗНОСОСТІЙКІ ГАЛЬВАНОПОРОШКОВІ КОМПОЗИЦІЙНІ ПОКРИТТЯ НА ЧОРНИХ МЕТАЛАХ

Термічна обробка у вакуумі та за допомогою лазера композиційних електролітичних покриттів складу *Ni+B* та $Ni+B+Cr_3C_2$ суттєво підвищує їх триботехнічні властивості. Зносостійкість підвищується зі збільшенням навантаження при терті. Оплавлення покриттів у вакуумі підвищує на порядок їх зносостійкість для покриттів *Ni+B* та на два для $Ni+B+Cr_3C_2$ покриттів, в той час як при плавленні за допомогою лазера в 7-21 разів. Це пов'язано з наявністю включень борида Ni_3B і евтектики *Ni-B-Cr-C*, що характеризуються високими механічними властивостями.

Ключові слова: композиційні електролітичні покриття, зносостійкість, термічна обробка, лазерна обробка.

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