STUDY OF PHYSICAL AND MECHANICAL PROPERTIES OF IRON-NICKEL COMPOSITE COATINGS MACRO INDENTATION

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1. INTRODUCTION

1.1. Research and testing of physical and mechanical properties of materials

The relevance of research and testing of physical and mechanical properties of materials at the surface and in the surface layers due to the fact that the contact interaction and contact deformation associated with nearly all modern methods of treatment, hardening and metal compounds, but also service properties of metals in terms of friction, fatigue, seizure and wear.

One of their methods of testing the surface properties of materials - test macrohardness.

1.2. The common information

In recent years developed methods and devices, allowing obtaining a wealth of information about the properties of materials at macro indentation. Material test method allows macro indentation measure several important parameters characterizing the physical and mechanical properties of composite plating, traditional and new, obtained only when these tests.

The method of investigation of physical and mechanical properties of the coating is based on recording the kinetic diagram of a spherical diamond indenter indentation.

As the spherical diamond indenter was used with artificial diamond sphere radius equal 1mm. Tests subjected composites, iron-nickel coating with a thickness of 0.5 mm, while the diameter of the sample was 30mm.

Test method for macrohardness allows testing of the wide application of materials with a thickness of 1 mm or more. Thus it is possible to determine not only the strength characteristics of the material but also its elastic-plastic properties.

Many researchers have studied the shape of the plastically deformable deformation zones, and in the nature of a screen where the fingerprint shown that the boundary area of plastically deformable nature of the deformation and the diameter d a fingerprint similar in shape to the part of a sphere for both metals and polymers.

We studied the deformation of deep and surface layers of materials under the indenter by applying a grid meridian section in the plane of the sample. We prove that the maximal deformation axis indentation depth of approximately half the radius of the print at the point of maximum shear stress. On the surface indentation deformation grow from the centre of the contour near the circuit decreases and beyond change direction. Inverting the direction of deformation occurs due to the fact that the printout at some distance underneath the material undergoes axial compression and broadening in the radial direction.

This paper presents the study of physical and mechanical properties of Fe-Ni composite coatings by indentation spherical diamond indenter.

Experimentally determined: elastic-plastic characteristics (he, hp, h); work spent on elastic (Ae), plastic (Ap), and the total deformation (A); not restored (Hh) and dynamic (Hd) hardness, indentation load on a spherical diamond indenter (P), the volume of elastic (Ve), a plastic (Vp) and the total (V) of a deformable composite material of iron-nickel coatings produced from the electrolyte 4 [2]. The above characteristics were determined at the facility for the study of the hardness of materials in macro volume equipped with an inductive sensor and a differential amplifier to record chart indentation spherical diamond indenter and indentation recovery after unloading.

The dynamic hardness (Hd) was determined as the ratio of the total of (A) consumed for the total deformation of the material (V) the volume of deformable material all studied Fe-Ni coating.

2. EXPERIMENTAL STUDIES.

Studies have shown that the investigated characteristics of composite iron-nickel coatings vary with the conditions of their receipt (D_K, T).

With increasing current density (CD) of from 5 to 80 ($\times 10^{-4}$ kA/m^2) at a constant temperature of electrolysis (40^{0}C), the elastic indentation depth (he) and the amount of elastic indentation of the coating

Table 1. Elastic properties of hardness and **Fe-Ni** composite coatings

Terms electrolyze		***Hh, H/mm^2 (h=2μm)***	***Hd, H/mm^2***	***P, H***	***Elastic properties of the Fe-Ni coating***		
Dk, $\times 10^{-4}$ кA/m^2	***T,^{0}C***				***he, μm***	***Ae H×mm***	***Ve, $\times 10^{-7}$ mm^3***
5	40	3630	2422	45,6	1,134	0,01723	40,34
10	40	3670	2449	46,1	1,150	0,01767	41,47
20	40	3800	2534	47,7	1,172	0,01863	43,11
30	40	3980	2656	50,0	1,210	0,02017	45,93
40	40	4120	2746	51,7	1,240	0,02137	48,23
50	40	4470	2980	56,1	1,26	0,02356	49,80
60	40	4020	2683	50,5	1,28	0,02020	51,40
80	40	3320	2215	41.7	1,35	0,01577	57,17

material (Ve) increases, respectively, from 1.134 to 1.35 (microns) and from 40.34 to 57.17×10^{-7} (mm^3) Table 1. Dependence is not restored by the hardness (Hh), a dynamic hardness (Hd) on the indenter load (P) and the work consumed by the elastic deformation of coatings (Ae) are extreme. With increasing current density from 5 to 50 (×10^{-4} $_K$A/m^2), hardness (Hh) increased from 3630 to 4470 (N/mm^2), the dynamic hardness (Hd) increased from 2422 to 2890 (N/mm^2), load spherical diamond indenter increased from 45.6 to 56.1 (H), and the work spent on the elastic deformation Fe-Ni composite coatings (Au) increased from 17.23×10^{-3} to 23.56×10^{-3} (N.mm). With further increasing current density from

Table 2. Plastic properties and hardness **Fe-Ni** composite coatings.

Terms electrolyze		***Hh, H/mm^2 (h=2μm)***	***Hd, H/mm^2***	***P, H***	***Plastic properties of the Fe-Ni coating***		
Dk, $\times 10^{-4}$ кA/m^2	***T,^{0}C***				***hp, μm***	***Ap H×mm***	***Vp, $\times 10^{-7}$ mm^3***
5	40	3630	2422	45,6	0,8660	0,01316	23,57
10	40	3670	2449	46,1	0,8500	0,01351	22,67
20	40	3800	2534	47,7	0,8280	0,01357	21,50
30	40	3980	2656	50,0	0,7900	0,01361	19,56
40	40	4120	2746	51,7	0,7600	0,01369	18,11
50	40	4470	2980	56,1	0,7400	0,01384	17,17
60	40	4020	2683	50,5	0,7200	0,01212	16,26
80	40	3320	2215	41,7	0,6500	0,00904	13,25

50 to 80 (×10^{-4} KA/m^2). Hardness (Hh) decreased from 4470 to 3320 (N/mm^2), the dynamic hardness (Hd) decreased from 2980 to 2215 (N/mm^2), the load on the diamond spherical indenter (P) decreased from 56.1 to 41.7 (H) and the work spent on the elastic deformation (Ae) Fe-Ni composite coatings decreased from 23.56×10^{-3} to 15.77×10^{-3} (N/mm).

Extreme hardness (Hh), a dynamic hardness (Hd), load on a spherical diamond indenter (P) and the work consumed by the elastic deformation of Fe-Ni composite coatings coincide with the existing guidelines for the choice of electrolysis conditions for optimum Fe-Ni coating from the standpoint their wear resistance. With increasing current density (D_K) Table 2, from 5 to 40 (×10^4 kA/m^2) electrolysis at constant temperature (40^{0}C) plastic indentation depth (hp) and the volume of plastic indentation test material (Vp), respectively, are reduced from 0.866 to 0.740 (microns) and from 23.57×10^{-7} do 17.17×10^{-7} (mm^3). density increases from 5 to 50 (×10^{-4} kA/m^2) electrolysis at constant temperature (40^{0}C) hardness (Hh), a dynamic hardness (Hd), indentation load (P) increased as in the previous case (Table 1), and the work expended in plastic deformation (Ap) Fe-Ni composite coatings increased from 13.16 to 13.84×10^{-3}(H×mm, table 2).

With a further increase in current density (Dk) at a constant temperature of electrolysis (40^{0}C) of 50 to 80 (×10^{-4}kA/m2) hardness (Hh), a dynamic hardness (Hd), indentation load (P) is decreased as in the preceding case (table 1), and the work expended in plastic deformation of Fe-Ni composite coatings decreased from 13.84×10^{-3} to 9.04×10^3 (H×mm, table 2).

Table 3. Elastic-plastic properties and hardness of Fe-Ni composite coatings.

Terms electrolyze		Hh, H/mm2 (h=2μm)	Hd, H/mm^2	P, H	Elastic-plastic properties		
Dk, $\times 10^{-4}$ $\kappa A/m^2$	$T,^0C$				he, μm	Ae, H×mm	Ve, $\times 10^{-7} mm^3$
5	40	3630	2422	45,6	2,0	0,03040	125,51
10	40	3670	2449	46,1	2,0	0,03073	125,51
20	40	3800	2534	47,7	2,0	0,03180	125,51
30	40	3980	2656	50,0	2,0	0,0333	125,51
40	40	4120	2746	51,7	2,0	0,0347	125,51
50	40	4470	2980	56,1	2,0	0,03740	125,51
60	40	4020	2683	50,5	2,0	0,0337	125,51
80	40	3320	2215	41,7	2,0	0,02780	125,51

Table 4. Elastic properties of hardness and Fe-Ni coating.

Terms electrolyze		Hh, H/mm2 (h=2μm)	Hd, H/mm^2	P, H	Elastic-plastic properties		
Dk, $\times 10^{-4}$ $\kappa A/m^2$	$T,^0C$				he, μm	Ae, H×mm	Ve, $\times 10^{-7} mm^3$
50	20	3320	2215	41,7	1,52	0,02113	72,50
50	40	4470	2980	56,1	1,260	0,02356	49,80
50	60	3630	2422	45,6	1,028	0,01563	33,15

And in this case, the extreme hardness (Hh), dynamic hardness (Hd), indentation load (P) and the work expended in plastic deformation (Ap) Fe-Ni composite coatings coincide with existing recommendations for choosing electrolysis conditions to obtain optimal properties Fe-Ni coatings in terms of wear resistance [2].

With increasing current density (Dk) in Table 3, from 5 to 80 (10^{-4} kA/m^2) (at a constant temperature of electrolysis (40^{0}C) total indentation depth (h) and a common pressed into the coating material volume (V) are constant and equal to 2.0, respectively (m) and 125.51 x 10^{-7} (mm^3).

With increasing current density (Dk) from 5 to 50×10^{-4} kA/m^2 at a constant temperature of electrolysis (40^{0}C), hardness (Hh), a dynamic hardness (Hd) indentation load (P) increases in both the previous cases (Table 1 and 2), and the work expended on the deformation of Fe-Ni composite coatings (A) increased from 30.4×10^{-3} to 37.4×10^{-3} (H×mm, table 3).

With further increase of the current density (Dk), with electrolysis constant temperature (40^{0}C) of 50 to 80 (10^4 kA/m^2) Hardness (Hh), a dynamic hardness (Hd), pressing load by spherical diamond indenter (P) decreases as in the previous case (table 1 and 2) and total work expended on the deformation of Fe-Ni composite coatings decreased from 37.4 to 27.8×10^{-3} (H×mm, table 3).

In this case, the experimental values of hardness (Hh), a dynamic hardness (Hd), pressing load of the spherical diamond indenter (P) and work spent on the total deformation of Fe-Ni composite coatings (A) coincide with the existing recommendations on the choice of conditions electrolysis to obtain optimal properties of Fe-Ni composite coatings in terms of wear resistance.

With increasing temperature electrolysis (T) for obtaining Fe-Ni composite coatings (Table 4) of 20 to 60^{0}C (Dk=50x10^{-4} kA/m^2), the elastic component of the depth of the indentation (he) decreased from 1.52 to 1.028 micron, print volume (Ve) also decreased from 72.5×10^{-7} to 33.15×10^{-7} mm^3. With increasing temperature electrolysis from 20 to 40^{0}C, hardness (Hh) has increased from 3320 to 4470 (N/mm^2), dynamic hardness (Hd) increased from 2215 to 2980 N/mm^2, indentation load on the diamond spherical indenter (P) increased from 41,7 to 56.1 (H), the work spent on the elastic deformation of Fe-Ni composite coatings (Ae) increased from 21.13 x 10^{-3} to 23.56 x 10^{-3} (N.mm), and the volume of print on elastic deformation of coatings (Ve) decreased from 72.5 x 10^{-7} to 49.8 x 10^{-7} (mm^3, table 4).

Table 5. Plastic properties and hardness Fe-Ni composite coating.

Terms electrolyze		***Hh, H/mm²* *(h=2µm)***	***Hd, H/mm²***	***P, H***	***Elastic-plastic properties***		
Dk, ×10⁻⁴ кA/m²	***T,⁰C***				***hp, µm***	***Ap, H×mm***	***Vp, ×10⁻⁷mm³***
50	20	3320	2215	41,7	0,480	0,00667	7,22
50	40	4470	2980	56,1	0,740	0,01384	17,17
50	60	3630	2422	45,6	0,972	0,01877	29,64

Table 6. Elastic-plastic properties and hardness of the composite coatings Fe-Ni.

Terms electrolyze		***Hh, H/mm²* *(h=2µm)***	***Hd, H/mm²***	***P, H***	***Plastic properties***		
Dk, ×10⁻⁴ кA/m²	***T,⁰C***				***h, µm***	***A, H×mm***	***V, ×10⁻⁷mm³***
50	20	3320	2215	41,7	2,0	0,02780	125,51
50	40	4470	2980	56,1	2,0	0,03740	125,51
50	60	3630	2422	45,6	2,0	0,03040	125,51

With further increase of the electrolysis temperature (T) of 40^0C to 60^0C, a hardness (Hh) was reduced from 4470 to 3630 (N/mm^2) dynamic hardness (Hd) decreased from 2980 to 2422 (N/mm^2), the load on a spherical diamond indenter (P) decreased from 56.1 to 45.6 (H), and the work spent on the elastic deformation (Ae) Fe-Ni composite coatings decreased from 23.56×10^{-3} to 15.63×10^{-3} (H×mm, table 4).

In this case, the experimental values of hardness (Hh), a dynamic hardness (Hd), at indentation load spherical diamond indenter (P), the work expended in elastic deformation Fe-Ni composite coating (Ae), depending on the electrolysis temperature (T) at constant current density (Dk= 50 x 10^{-4} kA/m^2) coincide with current recommendations for choosing electrolysis conditions to obtain optimal properties of Fe-Ni composite coating with the point of view of their optimal durability [2].

With increasing temperature electrolysis (T), upon receipt of Fe-Ni composite coating (see Table 5) of 20^0C to 60^0C (with Dk=50×10^{-4} kA/m^2) plastic components extrusion depth (hn) increased from 0.48 to 0,972 (µm) and the volume of print for plastic indentation (Vp) increased from 7.22×10^{-3} to 29.64×10^{-3} (mm^3).

With increasing temperature electrolysis from 20^0C to 40^0C hardness (Hh), dynamic hardness (Hd), indentation load on diamond spherical indenter (P) increased in value as in the previous case (Table 4), and the work expended in plastic deformation (Ap is) composite coatings Fe-Ni increased from 6.67×10^{-3} to $13,84\times10^{-3}$ (H×mm).

With further increase in temperature electrolysis (T) from 40^0C to 60^0C hardness (Hh) dynamic hardness (Hd), indentation load on the diamond spherical indenter (P) decreased in value as in the previous case (Table 4), and the work expended in plastic deformation Fe-Ni composite coatings (Ap) decreased from 13.84×10^{-3} to 18,77 $\times10^{-3}$ (H×mm, table 5).

With increasing temperature electrolysis (T) of 20^0C to 60^0C, in preparing the Fe-Ni composite coating at a constant current density (Dk =50×10^{-4} kA/m^2), estimated penetration depth (h) of the diamond and the amount of spherical indenter indentation (V) under elastic-plastic indentations are constants and are respectively 2,0 (µm) and 125.51x10^{-7} (mm^3) table 6.

With increasing temperature electrolysis (T) 20^0C to 40^0C, at a constant current density (Dk = 50×10^{-4} kA/m^2) hardness (Hh), a dynamic hardness (Hd), at indentation load spherical diamond indenter (P), increasing in value as in the previous case (Table 4 and 5) and the work spent on elastic-plastic indentations Fe-Ni composite coatings with indentations increased from 27.8×10^{-3} to 37.4×10^{-3} (N×mm).

With further increase in temperature electrolysis (T) from 40^0C to 60^0C (at Dk = 50×10^{-4} kA/m^2), hardness (Hh), dynamic hardness (Hd), indentation load on the diamond spherical indenter (P) decreased in value as in the previous cases (table 4 and 5), and the work spent on elastic-plastic deformation Fe-Ni composite coatings decreased from 37.4×10^{-3} to 30.4×10^{-3} (N×mm). As in previous cases (table 4 and 5) with increasing temperature electrolysis (T), hardness (Hh), dynamic hardness (Hh), the load on the spherical indentation diamond indenter (P) and the work spent on elastic-plastic deformation of Fe-Ni composite coatings is experimental.

One of the problems of engineering prediction of wear resistance of materials. In this sense, the test method for hardness macro volume treat micromechanical testing, allowing the most justified approach this material characteristics.

The obtained dimensions of the Hh, Hd, P, A have a good correlation to the intensity of wear of the iron -nickel composite coating.

Thus, the parameters Hh, Hd, P, A can be used in the future to clarify the description of the wear rate of materials. Depending on the choice of the wear rate on these parameters based on the notions of additive contributions of these structural indicators [1].

Research results have shown that the parameters Hh, Hd, P, A taking into account the elastic-plastic properties Fe-Ni composite coatings have extreme character as the wear rate with changing conditions electrolyze (Dk, T).

3. CONCLUSION

Established not restored hardness (Hh) and the dynamic hardness (Hd), the work spent on elastic-plastic deformation (A) have extreme character changes in the conditions of electrolysis (Dk, T) for the study of iron-nickel composite coatings.

Experimental values not restored hardness (Hh), dynamic hardness (Hd), indentation load diamond spherical indenter (P), the work spent on plastic (Ap) and elastic-plastic deformation (A) coincides with our earlier recommendations for iron-nickel composite coatings with the point of view of their optimum durability.

Physical and mechanical characteristics (Hh, Hd, P, Ap, A) iron-nickel composite coatings have a good correlation with the intensity of wear of these coatings.

Physical and mechanical characteristics (Hh, Hd, P, Ap, A) can be used to refine the description of the wear rate of iron-nickel composite coatings.

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