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FEATURES OF ELASTOPLASTIC DEFORMATIONS OF COMPOSITE IRON-NICKEL COATINGS AND THEIR IMPACT ON THE INTENSITY OF WEAR

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Lucrare prezintă caracteristicile deformaţiilor elastoplastice şi a ruperii fragile a acoperirilor compozite de fier-nichel obţinute prin depunerea electrolitică. Caracteristicile fizico-mecanice (H_h; H_d; A_e; A_p; A; P; H_h/E; H_d/E) pot fi utilizate pentru a perfecţiona descrierea vitezei de uzurăa acoperirilor de fier-nichel.

Cuvinte-cheie: acoperiri de fier-nichel, compozit, viteză de uzură, proprietăţile fizico-mecanice, deformaţiile elastoplastice.

The paper presents some features of elastoplastic deformation and brittle fracture of iron-nickel composite coatings obtained at electrolyte deposition. Physico-mechanical characteristics (H_h; H_d; A_e; A_p; A; P; H_h/E; H_d/E) can be used to improve the description of wear rate of iron-nickel coatings.

Keywords: iron-nichel coatings, composite, wear rate, physico-mechanical properties, elastoplastic deformation.

1. INTRODUCTION

Electrolytic wear-resistant coatings are widely used for hardening and restoration parts in the industry in order to increase their longevity. Electrodeposition conditions have a significant impact on the physical and mechanical properties of wear-resistant plating. Knowledge of physical and mechanical characteristics of wear-resistant plating needed to make informed choices technological conditions of deposition, depending on the operating conditions of the recovered parts of machines, as well as for important structural calculations [1-3].

2. GENERAL INFORMATION

Actual problems of study of physical and mechanical properties of materials in the surface and the surface layers due to the fact that the deformations associated with contact with modern methods of treatment and hardened metal compounds. Test kinetic hardness and microhardness opens up new possibilities for the determination of physical and mechanical properties and fracture toughness of electrolytic plating coating [1-3].

An important parameter in the study of physical and mechanical characteristics of wear-resistant plating is their fragility. This property plating is undesirable since the craze fragility affects such important characteristic as wear resistance [2]. The importance of identifying the characteristics of elastic-plastic (**he**, **hp**, **h**) required for robot deformation (**Ae**, **Ap**, **A**), unrestored and dynamic hardness (**Hh**, **Hd**) modulus (**E**), the critical load indentation diamond spherical indenter with a start brittle fracture ($\mathbf{P_{CR}}$), the ratio of non-reduced and dynamic hardness to elastic modulus (**Hh/E, Hd/E**), yield strength ($\boldsymbol{\sigma_T}$), the true tensile strength ($\mathbf{S_B}$), tensile strength ($\boldsymbol{\sigma_b}$), yield strength ($\boldsymbol{\sigma_{0,2}}$) toughness ($a_H$), the degree of deformation of the material in the contact zone (**ψ**) is invaluable.

The paper presents some features of elastoplastic deformation and brittle fracture of iron-nickel composite coatings obtained from electrolyte 4 [2, p. 59]. The samples used rollers with diameter 30 mm, thickness of the coating 0.5 mm and a length of 100 mm, which were processed under optimal grinding. Physico-mechanical characteristics were determined at the facility for the study of the hardness of materials in macrovolume equipped with an inductive sensor and a differential amplifier allows you to record chart indentation diamond spherical indenter and indentation recovery after removal of the load [2].

Dynamic hardness (**Hd**) was determined as the ratio of the total work expended by elastoplastic deformation of (**A**) to the volume of deformable material (**V**) under load, in all investigated iron-nickel composite coating.

3. DISCUSSION OF EXPERIMENTAL RESEARCH

Studies have shown that the investigated physical and mechanical properties of iron-nickel composite coatings vary with the electrolysis conditions (tables 1 and 2).

Table 1

Physico-mechanical properties of Fe-Ni composite coatings

Electrolysis conditions		***Work expended on the deformation of coatings***			H_h N/mm^2 (h=2μm)	H_d N/mm^2	P, N	P_{cr}, N	E, ×10^{-4}, N/mm^2	H_h/E	H_d/E
Dк, ×10^{-4} kA/m^2	T, °C	A_e N·mm	A_p N·mm	A N·mm							
5	40	0.0172	0.0132	0.0304	3630	2422	45.6	350	21.0	0.0173	0.0115
10	40	0.0177	0.0135	0.0312	3670	2449	46.1	335	20.5	0.0179	0.0119
20	40	0.0186	0.0132	0.0318	3800	2534	47.7	320	19.8	0.0192	0.0128
30	40	0.0202	0.0132	0.0334	3980	2686	50.0	300	19.5	0.0204	0.0136
40	40	0.0214	0.0132	0.0346	4120	2746	51.7	275	19.3	0.0213	0.0142
50	40	0.0235	0.0138	0.0373	4470	2980	56.1	260	18.8	0.0238	0.0159
60	40	0.0202	0.0121	0.0323	4020	2683	50.5	245	18.0	0.0223	0.0149
80	40	0.0188	0.009	0.0278	3320	2215	41.7	215	17.5	0.0190	0.0127

With increasing current density (**Dk**) of 5×10^{-4} to 80×10^{-4} kA/m^2 electrolysis at a constant temperature (40 ^{o}C), the critical load (**Pcr**) and the iron-nickel coatings modulus (**E**) is reduced accordingly from 350 to 215 (**H**) and from 21×10^{-4} to 17.5×10^{-4} (N/mm^2). Work expended in elastic (**Ae**), plastic (**Ap**), unrestored hardness (**Hd**), dynamic hardness (**Hd**), the indentation load on the diamond spherical indenter (**P**) ratio **Hh/E** and **Hd/E** have extreme values with the change of the current density (**Dk**) from 5×10^{-4} kA/m^2 80×10^{-4} kA/m^2 to electrolysis at a constant temperature (40 °C). Physico-mechanical properties of iron-nickel coatings (table 1 and 2) determined for one indentation depth (h=2μm) by a known method [2].

Studies have shown that with increasing current density of 5×10^{-4} to 50×10^{-4} kA/m^2 electrolyte at a constant temperature (40 °C) the work expended in elastic deformation coverage increased from 17.2×10^{-3} to 23.5×10^{-3} (N·mm), the work expended in plastic deformation, coatings increased from 13.2×10^{-3} to 13.8×10^{-3} (N·mm), the total work spent on elastoplastic deformation of the coating increased from 30.4×10^{-3} to 37.3×10^{-3} (N·mm). With further increase of the current density of 50×10^{-4} to 80×10^{-4} kA/m^2, electrolysis at a constant temperature (40 °C) work spent on elastic deformation of coatings decreased from 23.5×10^{-3} to 18.8×10^{-3} (N·mm) total work spent on plastic deformation decreased from 13.8×10^{-3} to 9.0×10^{-3} (N·mm), the total work spent on elastoplastic deformation of coatings decreased from 37.3×10^{-3} to 27.8×10^{-3} (N·mm). From the results of research can be seen that the work expended in elastic (**Ae**), plastic (**Ap**) and elastic-plastic (**A**) deformation of iron-nickel coatings at a constant temperature electrolysis are extreme.

Character changes unreduced hardness (**Hh**), dynamic hardness (**Hd**) and extrusion load the diamond spherical indenter at a depth of 2 μm with increasing current density of 5×10^{-4} to 80×10^{-4} (kA/m^2), at a constant temperature electrolysis (40 °C) has an extreme character.

With increasing current density of 5×10^{-4} to 50×10^{-4} (kA/m^2) unrestored coating hardness (**Hh**) increased from 3630 to 4470 (N/mm^2), dynamic coating hardness **Hd** increased from 2422 to 2980 (N/mm^2) and the indentation load on the diamond spherical indenter (**P**) increased from 45.6 to 56.1 (N). With further increase in current density (**DK**) from 50×10^{-4} to 80×10^{-4} (kA/m^2) at constant temperature electrolysis (40 °C) hardness unrestored (**Hh**) decreased from 4470 to 3320 (N/mm^2) dynamic coating hardness decreased from 2980 to 2215 (N/mm^2) and the indentation load on the diamond spherical indenter decreased from 56.1 to 41.7 (N) (table 1).

With increasing temperature electrolysis (T, Table 2) at a constant current density (D_K=50×10^{-4} kA/m^2) from 20 to 60 ^{o}C, the critical load indentation on diamond spherical indenter characterizes the beginning of brittle fracture of iron-nickel coatings and the elastic modulus of the coating increases, respectively, from 205 to 315 (N) and from 17.1×10^{-4} to 20.5×10^{-4} (N/mm^2).

Table 2

Physico-mechanical properties of Fe-Ni composite coatings

Electrolysis conditions		***Work expended on the deformation of coatings***			Hh N/mm^2 (h=2μm)	Hd, N/mm^2	P, N	Pcr, N	E, ×10^{-4} N/mm^2	Hh/E	Hd/E
Dк, ×10^{-4} kA/m^2	T, ˚C	Ae, N·mm	Ap, N·mm	A, N·mm							
50	20	0,0211	0,0067	0,0278	3320	2215	41,7	205	17,1	0,0194	0,013
50	40	0,0235	0,0148	0,0383	4470	2980	56,1	260	18,8	0,0238	0,0159
50	60	0,0156	0,0138	0,0294	3630	2422	45,6	315	20,5	0,0177	0,0118

Nature of the change work expended in elastic (**Ae**), plastic (**Ap**) and elastic-plastic deformation (**A**) of iron-nickel coatings with temperature electrolysis from 20 to 60°C at a constant current density (Dk=50×10^{-4} kA/m^2) also has an extreme character. With increasing temperature, the cell from 20 to 40 °C at a constant current density (Dk=50×10^{-4} kA/m^2), the work expended in elastic (**Ae**), plastic (**Ap**) and elastic-plastic deformed (**A**) increased respectively from 21.1×10^{-3} to 23.5 ×10^{-3} (N·mm) from 6.7×10^{-3} to 14.8×10^{-3} (N·mm), and from 27.8×10^{-3} to 38.3×10^{-3} (N·mm). With further increase of the temperature (**T**) of the cell from 40 to 60 °C at a constant current density (Dk=50×10^{-4} kA/m^2) work spent on elastic (**Ae**), plastic (**Ap**) and elastic-plastic deformation (**A**) iron-nickel coatings decreased correspondingly from 23.5×10^{-3} to 15.6×10^{-3} (N·mm) of 14.8×10^{-3} to 13.8×10^{-3} (N·mm), and from 38.3×10^{-3} to 29.4×10^{-3} (N·mm).

Character of change of hardness unreduced (**Hh**), a dynamic hardness (**Hd**), and the load - spherical indentation diamond indenter at a depth of 2 microns from the electrolysis temperature increases from 20 to 60 °C at a constant current density (Dk=50×10^{-4} kA/m^2) have also extreme. With increasing temperature electrolysis (**T**) from 20 to 40 °C at a constant current density (Dk=50×10^{-4} kA/m^2) unrestored hardness (Hh) has increased from 3320 to 4470 (N/mm^2), dynamic hardness (**Hd**) increased from 2215 to 2980 (N/mm^2), and the load - indentation diamond spherical indenter (**P**) increased from 41.7 to 56.1 (N). With further increase of the temperature of the cell from 40 to 60 °C at a constant current density (Dk=50×10^{-4} kA/m^2) not restored hardness (Hh) decreased from 4470 to 2422 (N/mm^2), dynamic hardness (**Hd**) decreased from 2980 to 2422 (N/mm^2), and the load - indentation diamond spherical indenter (**P**) decreased from 56.1 to 46.5 (N).

Much attention in the study of physical and mechanical properties of wear-resistant plating on defining their tendency to brittle fracture. The fragility of the coating is significantly affected by the conditions of their electrodepositing [2].

Increase in current density (**Dk**) and the electrolysis temperature (**T**) coatings tendency to brittle fracture increases. Composition of the electrolyte, which is obtained from wear-resistant coatings, can have a different impact on the considered properties of the coatings [2].

It was proved that the method of measuring the hardness of the coatings at different loads (up to **Pcr**) unrestored hardness (**Hh**) is constant. With further increase in load (>**Pcr**) is the value rises sharply, indicating a deviation from the mechanical similarity. On the regularities of a significant influence of electrolysis conditions coatings [2].

With increasing current density and decreasing temperature electrolysis violation original pattern passes with less pressure on the diamond spherical indenter [2-8].

In studying the characteristics of elastic and plastic deformation of iron-nickel coatings obtained after processing the indentation diagrams showed that responsible for the results is the change in the character of elastic deformation depending on the loading condition.

Regardless of the subject to the iron-nickel coatings with increasing load on the diamond - spherical indenter elastic deformation component coatings first increase dramatically (up to **Pcr**) and then rises slightly (after **Pcr**).

This proves that the main reason causing the violation of the law of the mechanical similarity due to the onset of brittle fracture of iron-nickel coatings [1].

Comparing the value of critical load indentation (**Pcr**) for spherical diamond indenter with their values determined by observation of the formation of ring cracks around the indentation, it can be argued that the beginning of the destruction of the coatings can be determined much more accurately by measuring the indentation depth (**h**) and diamond spherical indenter critical load (**Pcr**), as to the formation of an annular crack growth is possible source and the formation of new cracks are difficult to watch for. Critical stress ($\mathbf{Hh_{cr}}$) can be taken as a criterion for evaluating the tendency to brittle fracture coatings.

Studying the effect of current density (**Dk**) and the electrolysis temperature (**T**) on the tendency of iron nickel coatings to brittle fracture showed that with increasing current density of 5×10^{-4} to 80×10^{-4} (kA/m^2) at a constant temperature electrolysis (40 °C) critical load indentation on diamond spherical indenter is reduced from 350 to 215 (H), indicating an increase in the propensity of iron-nickel coating to brittle fracture. With increasing temperature, the cell from 20 to 60 °C at a constant current density (Dk=50×10^{-4} kA/m^2), the critical load indentation on diamond spherical indenter is increased from 205 to 315 (N), indicating a decline in the propensity to brittle iron-nickel coatings destruction.

One of the problems of engineering is predicting wear resistance of materials. In that sense, the hardness test method applies to micromechanical testing, allowing the most reasonable approach to these material characteristics.

We obtained dimensional parameters **Hh**, **Hd**, **P**, **Pcr**, and the dimensionless **Hh/E** and **Hd/E** have a good correlation with the wear rate wear resistance of iron-nickel composite coatings. Ratio **Hh/E** and **Hd/E** into account the elastoplastic properties of iron-nickel coatings accurately describe the process of wear.

Thus parameters **Hh**, **Hd**, **Hh/E** and **Hd/E** can be used to further clarify the description of the wear rate on these parameters and is based on the concept of additive contributions of these structural indicators (1.3-8).

The results showed that the ratio **Hh/E** and **Hd/E** elastoplastic characteristics into account, iron-nickel coatings have extreme value, as previously discussed parameters (**Ae**, **Ap**, **A**, **Hh**, **Hd**, **P**) with a change in the electrolysis conditions (**Dk**, **T**) for obtaining optimal properties of iron-nickel coatings in terms of their durability.

With increasing current density (**Dk**) of 5×10^{-4} to 50×10^{-4} (kA/m^2) at a constant temperature of electrolysis (40 °C) the ratio **Hh/Hd** and E/E (table 1), respectively, increases from 17.3×10^{-3} to 23.8×10^{-3} and 11.5×10^{-3} to 15.9×10^{-3}. With a further increase in current density (**Dk**) from 50×10^{-4} to 80×10^{-4} (kA/m^2) at a constant temperature of electrolysis (40 °C), the ratio **Hh/Hd** and **E/E** accordingly reduced from 23.8×10^{-3} to 19×10^{-3} and from 15.9×10^{-3} to 12.7×10^{-3}.

With increasing temperature electrolysis (**T**) from 20 to 40 °C at a constant current density (Dk=50×10^{-4} kA/m^2) ratio **Hh/E** and **Hd/E** increases from 19.4×10^{-3} to 23.8×10^{-3} and from 13×10^{-3} to 15.9×10^{-3}. With further increase of the temperature of the cell from 40 to 60 °C at a constant current density (Dk=50×10^{-4} kA/m^2) ratio **Hh/E** and Hd/E reduced accordingly from 23.8×10^{-3} to 17.7×10^{-3} and from 15.9×10^{-3} to 11.8×10^{-3}.

To evaluate the ability to predict the wear resistance of friction pairs as measured by thermal resistance of the boundary layer lubrication, anti-friction and physics - the mechanical properties of studies have been conducted to determine the wear of iron - nickel coatings rubbing against doped feed lubrication **M12B**. To assess the effect of physical - mechanical properties (**Ae**, **Ap**; **A**, **Hh**; **Hd**; **P**; **Pcr**; **Hh/E**; **Hd/E**) on the wear resistance of iron - nickel coatings studied the effect of current density (**Dk**) and the electrolysis temperature (**T**) on the wear resistance of the alloy iron - nickel (table 3 and 4) rubbing against alloyed iron feed lubrication **M12B**. Burnishing sampling began spending 150 N/cm^2 under load, which is then gradually increased to work. Closing break-in was fixed in magnitude of the frictional moment in the vicinity of the zone temperature friction and wear control by measuring the amount of samples. Duration wear chosen in light of the values of wear.

Microprobe analysis of iron - nickel plating conducted microanalyzer **MS-46** showed that increasing the current density of the nickel content in the coating decreases and increases with increasing temperature distribution besides nickel coating thickness is uniform, except for the exit area mode.

Table 3

Physico-mechanical properties and the wear rate of iron-nickel coatings rubbing against alloyed iron in the presence of oil M12B

Electrolysis conditions		***Work expended on the deformation of coatings***			Hh, N/mm^2 (h=2μm)	Hd, N/mm^2	P, N	Pcr, N	Hh/E	Hd/E	I, mg/hour
Dк, $\times10^{-4}$ kA/m^2	T, ˚C	Ae, N·mm	Ap, N·mm	A, N·mm							
5	40	0.0172	0.0132	0.0304	3630	2422	45.6	350	0.0173	0.0115	-
10	40	0.0177	0.0135	0.0312	3670	2449	46.1	335	0.0179	0.0119	4.8
20	40	0.0186	0.0132	0.0318	3800	2534	47.7	320	0.0192	0.0128	3.9
30	40	0.0202	0.0132	0.0334	2980	2556	50.0	300	0.0204	0.0136	2.6
40	40	0.0214	0.0132	0.0346	4120	2746	51.7	275	0.0213	0.0142	2.2
50	40	0.0235	0.0138	0.0373	4470	2980	56.1	260	0.0238	0.0159	1.8
60	40	0.0202	0.0121	0.323	4020	2683	50.5	245	0.0293	0.0149	2.6
80	40	0.0188	0.0090	0.0278	3320	2215	41.7	215	0.0190	0.0127	3.9

Table 4

Physico-mechanical properties and the wear rate of iron-nickel coatings rubbing against alloyed iron in the presence of oil M12B

Electrolysis conditions		***Work expended on the deformation of coatings***			Hh, N/mm^2 (h=2μm)	Hd, N/mm^2	P, N	Pcr, N	Hh/E	Hd/E	I, mg/hour
Dк, $\times10^{-4}$ kA/m^2	T, ˚C	Ae, N·mm	Ap, N·mm	A, N·mm							
50	20	0.0211	0.0067	0.0278	3320	2215	41.7	205	0.0194	0.0130	2.42
50	40	0.0235	0.0148	0.0373	4470	2980	56.1	260	0.0238	0.0759	1.80
50	60	0.0156	0.0138	0.0294	3630	2422	45.6	315	0.0177	0.0118	2.21

To determine the effect of current density (**Dk**) and the electrolysis temperature (**T**) on the wear rate (tables 3 and 4) iron alloy coatings - nickel and its relationship with the physical - mechanical properties macrovolume (**Ae**, **Ap; A, Hh; Hd; P; Pcr; Hh/E; Hd/E**) specific tests. Precipitation of iron nickel alloy were obtained at a current density of 10×10^{-4}, 20×10^{-4}, 30×10^{-4}; 40×10^{-4}, 50×10^{-4}, 60×10^{-4} and 80×10^{-4} kA/m^2, wherein the electrolysis temperature was 40 °C, $P_H=0.8\div1.0$, which are worn in conjunction with iron - doped (table 3).

Other iron- nickel alloy precipitation were obtained at a current density of 50×10^{-4} kA/m^2, wherein the electrolysis temperature was varied 20, 40 and 60 °C at $P_H=0.8\div1.0$ (table 4) who also wore conjugation doped with iron.

Studies have shown that increasing the current density (**Dk**) from 10×10^{-4} to 50×10^{-4} (kA/m^2) at the electrolysis temperature 40 °C, $P_H=0.8\div1.0$ wear rate decreased from 4.8 to 1.8 (mg/hour) and then increased to 1.8 to 3.9 (mg/hour) (table 3), with increasing the current density (**Dk**) from 50×10^{-4} to 80×10^{-4} (kA/m^2).

With increasing temperature, the electrolysis of from 20 to 40 °C at a current density of 50×10^{-4} kA/m^2, $P_H=0.8\div1.0$ wear rate decreased from 2.4 to 1.8 (mg/hour). With further increase of the electrolysis temperature of 40 to 60 °C at a current density of 50×10^{-4} kA/m^2, $P_H=0.8\div1.0$ wear rate increased from 2.21 to 1.8 (mg/hour) (table 4).

The data patterns are in good agreement with the effect of the current density (**Dk**) and the electrolysis temperature (**T**) on the physical - mechanical characteristics of the iron-nickel coatings, temperature stability (**Tcr**) and wear rate of the coatings (table 3 and 4).

With increasing physico-mechanical properties of iron-nickel coatings (**Ae**, **Ap**; **A**, **Hh**; **Hd**; **P**; **Pcr**; **Hh**/**E**; **Hd**/**E**) (table 1 and 2) increased durability and improved anti-friction properties of an alloy of nickel and iron alloy cast iron.

Thus maximal values of physical - mechanical characteristics (**Ae**, **Ap**; **A**, **Hh**; **Hd**; **P**; **Pcr**; **Hh**/**E**; **Hd**/**E**) iron nickel coatings can make a selection of coatings obtained under different conditions of electrolysis in terms of their maximum durability. This will significantly reduce the time of the experiments, increasing the volume research that will significantly expand the scope of effectiveness studies iron nickel coatings industry.

4. CONCLUSION

It was established experimentally that the unreduced hardness (**Hh**), dynamic hardness (**Hd**), the work expended in elastic (**Ae**), plastic (**Ap**) elastic-plastic (**A**) deformation, the load on a spherical diamond indenter (**P** for **h**=2μm) ratio **Hh**/**E** and **Hd**/**E** is experimental conditions change electrolysis (**Dk**, **T**) for the study of iron-nickel coatings.

Experimental value unreduced hardness (**Hh**) dynamic hardness (**Hd**), the work expended in elastic (**Ae**), plastic (**Ap**), elastoplastic deformation (**A**) load on a spherical diamond indenter (**P**), the ratio **Hh**/**E** and **Hd**/**E** coincides with our earlier recommendations for iron-nickel coatings in terms of ensuring their optimum durability.

Experimentally established the beginning of brittle fracture of iron-nickel coatings (**Pcr**, $\mathbf{Hh_{cr}}$) with the changed conditions of electrolysis (**Dk**, **T**), the critical load (**Pcr**) indentation on diamond spherical indenter and the critical stress ($\mathbf{Hh_{cr}}$), which can be taken as a criterion for evaluating the tendency of coatings to brittle fracture.

The method of measuring the hardness in macrovolume allows most reasonably and accurately determine the physical and mechanical characteristics ($\mathbf{H_h}$; $\mathbf{H_d}$; $\mathbf{A_e}$; $\mathbf{A_p}$; **A**; **P**; $\mathbf{H_h}$/**E**; $\mathbf{H_d}$/**E**) iron-nickel coatings.

Physico-mechanical characteristics ($\mathbf{H_h}$; $\mathbf{H_d}$; $\mathbf{A_e}$; $\mathbf{A_p}$; **A**; **P**; $\mathbf{H_h}$/**E**; $\mathbf{H_d}$/**E**) iron-nickel coatings have good correlation with the intensity of wear of these coatings.

Physico-mechanical characteristics ($\mathbf{H_h}$; $\mathbf{H_d}$; $\mathbf{A_e}$; $\mathbf{A_p}$; **A**; **P**; $\mathbf{H_h}$/**E**; $\mathbf{H_d}$/**E**) can be used to refine the description of the wear rate of iron-nickel coatings.

BIBLIOGRAPHY

1. Булычев, С. И.; Алехин В. Н. Испытание материалов непрерывным вдавливанием индентора. Москва, Машиностроение, 1990, 224с.
2. Гологан, В. Ф.; Аждер, В. В.; Жавгуряну, В. Н. Повышение долговечности деталей машин износостойкими покрытиями. Кишинев, Изд-во Штиинца, 1979, 112 с.

3. Javgureanu, V.; Ajder, V.; Ceban, V.; Pavlova. The correlation of restored and unrestored microhardness of. Wear-proof iron plating. Conferință Științifică Internațională TMCR. Chișinău, 2003, p. 412-415.
4. Javgureanu, V.; Gordelenco, P.; Elita, M. The work of deforming wear -proof iron-nikel plating in microsquelging. The Annals of University "Dunărea de Jos" of Galați, Fascicle VIII, 2004, Tribology, Romania, pp.65-68.
5. Javgureanu, V.; Gordelenco, P.; Elita, M. Relationship of the restored and unrestored microharedbess of the cromium coating. The Annals of University "Dunărea de Jos" of Galaţi, Fascicle VIII, 2004 Tribology, Romania, pp.48-51.
6. Javgureanu, V.; Gordelenco, P.; Elita, M. Le rapport de la microdurete restauree et non restauree des convertures de crome. Conferință Științifică Internațională TMCR, Chișinău, 2005, pp. 166-169.
7. Жавгуряну, В.Н.; Годеленко, П. Соотношение восстановленной и невостановленой микротвердости хромовых покрытий. Международная НТК "Машиностроение и техносфера XXI века", Севастополь, 2005.
8. Жавгуряну, В.Н. Исследование работы деформации износостойких гальванических покрытий при микровдавливании. Международная НТК "Новые процессы и их модели в ресурсо и энергосберегающих технологий", Одесса, 2003, с.7-8.

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