ELASTOPLASTIC PROPERTIES INFLUENCE THE TENDENCY TO BRITTLE FRACTURE OF NICKEL-IRON COMPOSITE COATINGS”

Vasile JAVGUREANU, Pavel GORDELENCO

Technical University of Moldova

Abstract: *This paper presents the study of elastic-plastic properties (he, hp; h; Ae; Ap; A; H; Hh; Hh/H, E, P), taking into account the degree of compaction coefficient (K) and porosity (ρ) composite coatings of iron-specific method macro indentation. First experimentally determined coefficients taking into account the degree of compaction (K) and porosity (ρ) iron-nickel coatings with changing conditions of electrolysis (DK, T). It has been established that the increase of the current density (DK) and a decrease in temperature (T) of the electrolysis of iron-nickel coatings for, taking into account the power factor of the seal (K) coatings decreases and the porosity (ρ) increases coatings.*

Keywords: *elastoplastic, deformation, failure, galvanic, electrolytic, iron-nickel composite coatings.*

1. Introduction

Nickel-iron composite coatings are used to harden and restore parts of machines in the industry in order to increase their longevity. Electro deposition conditions have a significant impact on physical and mechanical properties of the coatings. Knowledge of the physical and mechanical characteristics of composite iron-nickel coatings is needed to make informed choices of deposition process conditions, depending on the operating conditions of remanufactured parts, as well as to perform strength calculations.

2. The common information.

Actual problems of study of physical and mechanical properties of materials on surface and subsurface layers are related to the fact that the deformations are associated with all modern methods of treatment, hardening and metal compounds.

Importance of determining the elastoplastic characteristics ($\mathbf{h_e}$, $\mathbf{h_p}$, **h**), the work required for deformation ($\mathbf{A_e}$, $\mathbf{A_p}$ is, **A**), unrestored and dynamic hardness ($\mathbf{H_h}$, $\mathbf{H_d}$), modulus of elasticity (**E**) coatings, the critical load indentation diamond spherical indenter in which begins the process of brittle fracture ($\mathbf{P_{cr}}$), the ratio of non-reduced and dynamic hardness to elastic modulus ($\mathbf{H_h/E}$, $\mathbf{H_d/E}$), yield strength ($\boldsymbol{\sigma_b}$), the true tensile strength ($\mathbf{S_b}$), tensile strength ($\boldsymbol{\sigma_v}$), toughness ($\boldsymbol{\alpha_H}$), the degree of material deformation in the contact zone ($\boldsymbol{\Psi}$) is invaluable.

An important parameter of iron-nickel composite coatings is their fragility. This property is undesirable because increase in brittleness affects such important characteristic as wear [2].

It is known that the fragility of coatings depends on substrate pretreatment conditions and electroplating. It can be caused by the inclusion of hydrogen coating, surface active agents (surfactants), metals and other foreign particles.

To determine the brittleness of sediments, a method based on bending of the plate is mainly used. Occurrence of a crack in the sediments and the bending angle of the plate, coating brittleness is evaluated. [2] In this case, the test results can depend on the nature of the material and thickness of the substrate plate. Moreover, using this method, researchers have information on the relative brittleness of coatings, excluding the applied voltage necessary for the formation of cracks in the coating. To this end, an attempt was made to use the indentation method [1-4] which allows to determine tension stress.

Electro deposition conditions have a significant effect on the fragility of coatings: with the increase of their stiffness (increased current density, decreasing the temperature of the electrolyte) it is significantly increased. The electrolyte composition may differently affect the properties of the coatings considered.

In the paper, elasto-plastic properties and their tendency to brittle fracture of iron-nickel composite coatings obtained from electrolyte 4 [2, p.59] are shown. The samples used in the rollers 30mm in diameter, thickness 0.5mm and length of 100mm, which were treated under optimal grinding. Physical and mechanical properties 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 that can record chart indentation diamond spherical indenter and indentation recovery after unloading.

The dynamic hardness (**Hd**) was determined as the ratio of the total of (**A**) consumed for elastoplastic deformation of the deformable volume indentation (**V**) under load, in all investigated iron-nickel composite coating. Coatings on the plastic deformation associated with the preparation of destruction is spent working ($\mathbf{A_p}$).

Currently, theoretical and experimental issues associated with the assessment of the properties of brittle materials indentation of a spherical indenter, are well developed [1-4].

Studies carried out in [2] showed that when a spherical indentation gradually increase in load on the indenter can reach a critical state in which the circumferential cracks are formed, approximately coinciding with the indentation diameter of coatings obtained under all conditions of electrolysis [2]. However, the critical condition occurs when the elastoplastic deformation, due to a small residual strain covering major difficulties in measuring the diameter of the indentation, so its boundaries are fixed on the contact patch. Furthermore, in this case before a continuous ring-cracks appear, new random direction cracks occur [2].

In scratching the critical load was recorded with cracks perpendicular to the direction of movement of the indenter. As with spherical indentation, brittle fracture occurred in the presence of plastic deformation. Due to fracture coatings formed during the test as new individual crack located at different angles to the direction of movement of the indenter [2].

Analysis of the results showed that in spite of the plastic deformation of the coating for all the studied sediments as under static indentation and scratching critical load varies as the radius of the sphere. With increasing current density, the critical state occurs at lower loads [2].

For comparison of theoretical and experimental values of the ratio of the critical load at slip ($\mathbf{P_{cr}}$) to the critical load under static indentation ($\mathbf{P_{st}}$) a formula was used, derived from the condition that the critical stress upon the occurrence of damage in case of static and dynamic indentation:

$$\frac{Pcr}{Pst} = \frac{1}{(1 + 3Af)^3} \qquad (1)$$

where: P_{cr} and P_{st} - critical load, respectively, scratching and static indentation.

f - the coefficient of friction between the indenter and the sample scratching.

To determine the values of A used the expression:

$$A = \frac{3\pi \cdot (4 + \mu)}{8 \cdot (1 - 2\mu)} \qquad (1)$$

where : μ - Poisson's ratio of coatings.

Studies have shown that using macro indentation selection of load and the diameter of the sphere is possible to determine the physical and mechanical properties of the coatings.

Despite the valuable information that can be detected by indentation with its use have difficulties associated with determining the diameter of the indentation and the onset of brittle fracture, which affects the plastic deformation of elastic coatings by immersion of the indenter. Besides hardness measurement method based on determination of the diameter of the impression, does not allow to obtain information about the nature of elastic materials. Therefore, to study the hardness of the coatings was used in macro volume hardness TCS -1 allows you to record chart indentation diamond spherical indenter and indentation recovery after unloading. Synthetic diamond indenter with spherical radius 1mm was used.

By measuring the physical and mechanical properties of iron coatings with different loads on the indenter (**P**) established that the loads (up to $\mathbf{P_{cr}}$) ratio: $\frac{P}{\pi \cdot D \cdot h}$ is a constant value. With further increase in load, this value rises sharply, indicating a deviation from the mechanical similarity. On regularities are strongly influenced by the conditions of electrolysis. With increasing current density violation original patterns occurs at lower loads on the indenter [2].

Study of features (h_e) elastic and plastic (h_p) strain coatings showed that responsible for the results obtained is the changing nature of the elastic deformation depending on the loading conditions. Regardless of the conditions for obtaining coatings with increasing load on the indenter elastic deformation component coatings first increases sharply and then it rises slightly [2].

The main reason that causes the violation of the law of the mechanical similarity is associated with the beginning of brittle fracture surfaces.

Comparing this critical loads with their values determined from observations form a ring crack, it can be argued that the onset of brittle fracture coatings can be determined much more accurately by measuring the depth of the indentation and the critical load ($\mathbf{P_{cr}}$) as to form an annular crack growth is possible source of cracks and the formation of new, behind which is difficult to observe. The critical stress can be taken as a criterion for evaluating the tendency to brittle fracture coatings.

3. Discussion of experimental studies.

Studies have shown that the elastic-plastic properties and susceptibility to brittle fracture of iron-nickel composite coatings vary with the electrolysis conditions (Table 1-4).

With increasing current density (**Дк**) of $5x10^{-4}$ to 80×10^{-4} kA/m^2 electrolysis at a constant temperature (40^0C), plastic indentation depth (h_p) and the critical load indentation (**P_{cr}**) for spherical diamond indenter is reduced accordingly from 2,598 to 0,0892 (μm) and 350 to 210 (N), and the elastic component of the indentation depth (**h_e**) is increased from 3,402 to 4,050 (μm), total indentation depth (N) of 6,0 (μm). Work expended in elastic (**A_e**), plastic (**A_p**), elastoplastic deformation (A) not restored (**H_h**), dynamic (**H_d**) hardness iron - nickel coatings, indentation load on the diamond spherical indenter (**P**) are the extreme value with changes in density current (**Дк**) from 5×10^{-4} to 80×10^{-4} kA/m^2 electrolysis at constant temperature (40^0C), table 1. Elastoplastic property iron-nickel coatings and their susceptibility to brittle fracture (Tables 1 and 2) were determined for a single indentation depth (h=6.0 μm) by a known procedure (2).

Studies have shown that with increasing current density from 5×10^{-4} to 50×10^{-4} kA/m^2 electrolysis at a constant temperature (40^0C), the work spent on the elastic deformation of coatings increased from 168.6×10^{-3} to 226×10^{-3}, (N×mm), the work expended in plastic deformation (**Ap**) coatings increased from 128.8×10^{-3} to 132.8×10^{-3} (N×mm), the work spent on the elastic-plastic deformation (A) coating increased from 297.4×10^{-3} to 358.8×10^{-3} (N×mm), unrestored coating hardness (**Hh**) coatings increased from 3930 to 4760 (N/mm^2), dynamic hardness (**Hd**) coatings increased from 2636 to 3181 (N/mm^2) and the indentation load on the diamond spherical indenter (**P**) increased from 148.7 to 179.4 (N).

Elastoplastic properties of iron-nickel composite coatings and their tendency to brittle fracture **Table 1.**

Electrolysis conditions		**H_h,** N /mm^2	**H_d,** N /mm^2	Elastoplastic properties						**P,** N	**P_{cr},** N
Дк, $\times10^{-4}$ кA/m^2	**T,** ^{0}C			**h_e,** μm	**A_e,** N·mm	**h_p,** μm	**A_p,** N·mm	**h,** μm	**A,** N·mm		
5	40	3930	2636	3,402	0,1686	2,598	0,1288	6,0	0,2974	148,7	350
10	40	3970	2652	3,450	0,1720	2,550	0,1272	6,0	0,2992	149,6	340
20	40	4120	2752	3,516	0,1819	2,484	0,1285	6,0	0,3104	155,2	320
30	40	4280	2860	3,630	0,1952	2,370	0,1274	6,0	0,3226	161,3	300
40	40	4440	2966	3,720	0,2075	2,280	0,1227	6,0	0,3202	167,3	280
50	40	4760	3181	3,780	0,2260	2,220	0,1328	6,0	0,3588	179,4	265
60	40	4320	2886	3,840	0,2084	2,160	0,1172	6,0	0,3256	162,8	245
80	40	3640	2432	4,050	0,1851	1,950	0,0892	6,0	0,2743	137,2	210

Elastoplastic properties of iron-nickel composite coatings and their tendency to brittle fracture **Table 2.**

Electrolysis conditions		**H_h,** N/mm^2	**H_d,** N/mm^2	Elastoplastic properties						**P,** N	**P_{cr},** N
Дк, $\times10^{-4}$ кA/m^2	**T,** ^{0}C			**h_e,** μm	**A_e,** N·mm	**h_p,** μm	**A_p,** N·mm	**h,** μm	**A,** N·mm		
50	20	3640	2432	4,560	0,2088	1,440	0,0659	6,0	0,2747	137,2	210
50	40	4760	3181	3,780	0,2260	2,220	0,1328	6,0	0,3588	179,5	265
50	60	3930	27636	3,084	0,1529	2,916	0,1446	6,0	0,2975	148,7	320

With increasing current density (**Дк**) from 50×10^{-4} to 80×10^{-4} KA/m^2, electrolysis at a constant temperature (40^0C) the work expended on elastic (**A_e**) deforming coatings decreased from 185.1×10^{-3} to 226×10^{-3} (N×mm), the work expended in plastic deformation coatings (**A_p**) decreased from $132,8\times10^{-3}$ to $89,2\times10^{-3}$ (N×mm), the work spent on elastoplastic deformation (A) coatings decreased from $358,8\times10^{-3}$ to $274,3\times10^{-3}$ (N×mm), unrestored coating hardness (**H_h**) decreased from 4760 to 3640 (N/mm^2), dynamic coating hardness (**H_d**) decreased from 3181 to 2432 (N/mm^2) and the indentation load on the diamond spherical indenter (**P**) decreased from 179.4 to 137,2 (N). From the results of the study (Table 1) shows that the work expended in elastic (**A_e**), plastic (**A_p**) elastic-plastic (**A**) deforming coatings unrestored (**H_h**), dynamic (**H_d**) hardness and load dented the diamond spherical indenter (**P**) monitoring the density of current (**Дк**) at a constant temperature of electrolysis (**T**) have extreme values (Table 1).

With increasing temperature electrolysis (**T**) from 20 to 60ºC (Table 2), at a constant current density (**Дк** =50×10^{-4} kA/m^2) critical load indentation (**P_{cr}.**) On diamond spherical indenter characterizes the beginning of brittle fracture of iron-nickel coatings plastic component (h_p) and the depth of the indentation work spent on plastic deformation of coatings (**A_p**) respectively increased from 210 to 320 (N/mm^2), from 1.44 to 2.916 (micrometers) and from 65.9×10^{-3} to 144.6×10^{-3} (N×mm), and elastic component (**h_e**) indentation depth decreased from 4.56 to 3.084 (micrometers).

Nature of the change work expended in elastic (**A_e**), elastoplastic deformation (**A**) coatings, unrestored (**H_h**), dynamic (**H_d**) coating hardness and load indentation (**P**) on the diamond spherical indenter at a depth of 6.0 micrometers are also extreme. With increasing temperature electrolysis (**T**) from 20 to 40ºC, at a constant current density (Дк) 50×10^{-4} kA/m^2 work spent on the elastic deformation of the coating increased to 208,8×10^{-3}, 226,0×10^{-3} (N×mm), the work expended elastoplastic deformation (**A**) increased from 274,7×10^{-3} to 358,8×10^{-3} (N×mm), unrestored hardness (**H_h**) coatings increased from 3640 to 4760 (N/mm^2), the dynamic hardness of the coatings increased from 2432 to 3181 (N/mm^2) and the indentation load (P) the diamond spherical indenter increased from 137.2 to 179.5 (N). With further increase of the temperature (T) of the cell from 40 to 60ºC, at a constant current density (**Дк**) 50×10^{-4} kA/m^2 work expended elastic deformation of coatings (**A_e**) decreased from 226.0×10^{-3} to 152.9×10^{-3} (N×mm), the work expended on the elastic-plastic deformation of the coating decreased from 358.8×10^{-3} to 297.5×10^{-3} (N×mm), unrestored coating hardness (H_h) decreased from 4760 to 3930 (N/mm^2) dynamic coating hardness (**H_d**) decreased from 3181 to 2636 (N/mm^2) and indentation load (**P**) on the diamond spherical indenter decreased from 179.5 to 148.7 (N), Table 2.

Study of the influence of the current density (**Дк**) and the electrolysis temperature (**T**), the tendency of iron-nickel coatings and brittle fracture, showed that an increase in current density (**Дк**) of 5×10^{-4} to 80×10^{-4} (kA/m^2) at a constant temperature electrolysis (40ºC), the critical load for pressing the spherical diamond indenter is reduced from 350 to 210 (N), indicating an increase in iron-nickel coatings tendency to brittle fracture. With increasing temperature, the electrolysis of from 20 to 60ºC, at a constant current density (**Дк**) 50×10^{-4} kA/m^2, the critical load for pressing the spherical diamond indenter (**P**) is increased from 210 to 320 (N) that indicates a decrease tendency of iron-nickel coatings to brittle fracture.

Is of great interest to determine the beginning of the brittle fracture of composite iron - nickel coatings in the indentation test. For most of the theoretical strength of materials review Tmax, significantly greater than the theoretical shear strength G max [1]. This is due to the fact that the sliding connection between the atoms, a plane perpendicular to the sliding periodically reversed. Degree of recovery of these relations define a measure of material ductility. Unrestored appearance bond equivalent of a new elementary surface on which creation is spent working, the measured surface energy [1].

On the plastic deformation associated with the preparation of destruction, work is expended. From this point of view, consider the change elasto-plastic properties of composite coatings when iron- early brittle fracture (P_{cp}, Tables 3 and 4).

With increasing current density (**Дк**) of 5×10^{-4} to 80×10^{-4} kA/m^2 electrolysis at a constant temperature (40ºC), the critical load (**P_{cr}**), elastoplastic properties (**h_e; h_p; h; A_e; A_p; A**) decreases, respectively, from 350 to 210 (N), from 7.15 to 5.6 (micrometers), from 3.95 to 1.8 (micrometers) from 11.1 to 7.4 (micrometers) from 834×10^{-3} to 392×10^{-3} (N×mm) from to 461×10^{-3} 126×10^{-3} (N×mm) from 1295×10^{-3} to 518×10^{-3} (N×mm). The volume of prints (**V**) under load also decreased from 38.47×10^{-5} to 17.13×10^{-5} (mm^3). The results demonstrate that the process of brittle fracture of iron-nickel coatings began. Work spent on plastic deformation and total iron- coating indentation significantly higher (respectively 126×10^{-3}, 461×10^{-3}, 518×10^{-3}, 1295×10^{-3} (N×mm) than in the previous case (Table 1 and 2), respectively, 89.2×10^{-3} - 128,8×10^{-3} and 274,3×10^{-3}, 358,8×10^{-3} (N×mm). This proves that the total plastic deformation and iron-nickel coatings spent significantly more work (A_p; A), which is associated with the preparation of brittle fracture surfaces.

With increasing current density (**Дк**) of 5×10^{-4} to 4, 80×10^{-4} kA/m^2, electrolysis at a constant temperature (40º C), unrestored critical hardness (voltage), the critical dynamic hardness (**H_{dcr}**) ratio **H_{hcr}/E** and **H_{dcr}/E** have extreme nature (Tables 3 and 4). Since the beginning to achieve brittle fracture composite iron - nickel coatings, the critical load is changed from 350 to 210 (N) and the overall penetration depth was varied from 11,1 to 7,4 (μm). Studies have shown that with increasing current density (**Дк**) of 5×10^{-4} to 50×10^{-4} (kA/m^2), at a constant temperature electrolysis (40°C), unrestored critical hardness (N) increased from 5021 to 5480 (N/mm^2), the critical dynamic hardness increased from 3366 to 3666 (N/mm^2), and the ratio **H_{hcr}/E** and **H_{dcr}/E** respectively increased from 0.0239 to 0.0291 and from 0.0162 to 0.0195.

Elastoplastic properties of composite iron-nickel coatings on reaching a critical state **Table 3.**

Electrolysis conditions		**$P_{кр}$**, N	**$H_{hкр}$**, N/мм^2	Elastoplastic properties						**V**, ×10^{-5} мм^3	**H_{dcr}**, N/мм^2	**H_{hcr} /E**	**H_{dcr} /E**
$Д_к$, ×10^{-4} кА/м^2	**T**, ^{0}C			**h_e**, μм	**A_e**, N·мм	**h_p**, μм	**A_p**, N·мм	**h**, μм	**A**, N·мм				
5	40	350	5021	7,15	0,834	3,95	0,461	11,1	1,295	38,47	3366	0,0239	0,0162
10	40	340	5013	6,8	0,771	4,0	0,453	10,8	1,224	36,45	3360	0,0245	0,0164
20	40	320	5045	6,68	0,713	3,42	0,365	10,1	1,078	31,87	3382	0,0255	0,0171
30	40	300	5082	6,1	0,610	3,30	0,330	9,4	0,94	27,61	3405	0,0261	0,0175
40	40	280	5124	5,83	0,544	2,87	0,268	8,7	0,812	23,66	3432	0,0265	0,0178
50	40	265	5480	5,33	0,471	2,37	0,209	7,7	0,68	18,55	3666	0,0291	0,0195
60	40	245	5133	5,41	0,442	2,19	0,179	7,6	0,62	18,08	3431	0,0285	0,0191
80	40	210	4519	5,6	0,392	1,8	0,126	7,4	0,518	17,13	3024	0,258	0,0173

Elastoplastic properties of iron-nickel composite coatings achieve the critical state Table 4.

Electrolysis conditions		**P_{cr}**, N	**H_{hcr}**, N/мм^2	Elastoplastic properties						**V**, ×10^{-5} мм^3	**H_{dcr}**, N/мм^2	**H_{hcr}** /E	**H_{dcr}** /E
$Д_к$, ×10^{-4} кА/м^2	**T**, ^{0}C			**h_e**, μм	**A_e**, N·мм	**h_p**, μм	**A_p**, N·мм	**h**, μм	**A**, N·мм				
50	20	210	3843	6,6	0,462	2,1	0,147	8,7	0,609	23,65	2574	0,0225	0,0151
50	40	265	5480	5,33	0,471	2,37	0,209	7,7	0,680	18,55	3666	0,0291	0,0195
50	60	320	4549	6,03	0,643	5,17	0,551	11,2	1,194	39,17	3051	0,0222	0,0149

With further increase of the current density from 50×10^{-4} to 80×10^{-4}(kA/m^2), at a constant temperature electrolysis (40°C) unrestored critical hardness (N) decreased from 5480 to 4519 (N/mm^2), the critical dynamic hardness (H_{dcr}) decreased from 3666 to 3024 (N/mm^2) and the ratio and correspondingly decreased from 0.0291 to 0.0258 and from 0.0195 to 0.0173.

With increasing temperature electrolysis of 20 to 60°C (Table 4) with a constant current density (**Дк**= 50×10^{-4} kA/m^2), the critical load (**P_{cr}**) characterizes the beginning of brittle fracture coatings elastoplastic properties (**h_e; h_p; h; A_e; A_p; A**) increases, respectively, from 5.33 to 6.6 (micrometers), from 8.7 to 11.2 (micrometers), from 462×10^{-3} to 643×10^{-3} (N×mm), from 147×10^{-3} to 551×10^{-3} (N×mm) and from 609×10^{-3} to 1194×10^{-3} (N×mm).

With increasing temperature, the cell from 20 to 40°C at a constant current density 50×10^{-4} kA/m^2 unrestored critical hardness (N) increased from 3843 to 5480 (N/mm^2), the critical dynamic hardness (**H_{dcr}**) increased from 2574 to 3666 (N/mm^2), the ratio **H_{hcr}/E** and **H_{dcr}/E** increased respectively from 0.0225 to 0.0291 and from 0.0151 to 0.0195, while the volume of indentation under load (V) decreased from 23.65×10^{-5} to 18.55×10^{-5} (mm^3).

With further increase of the temperature of the cell from 40 to 60°C at a constant current density (**Дк**=50×10^{-4} kA/m^2), unrestored (**H_{hcr}**) critical hardness (**N**) decreased from 5480 to 4549 (N/mm^2), the critical dynamic hardness (**H_{dcr}**) decreased from 3666 to 3051 (N/mm^2), and the ratio decreased, respectively, from 0.0291 to 0.0222 and from 0.0195 to 0.0149, while the volume of indentation load (**V**) increased from 18.55×10^{-5} to 39.17×10^{-5} (mm^3). In this case the results obtained confirm the brittle fracture start composite iron - nickel coatings (Table 4). With increasing temperature, the electrolysis of from 20 to 60°C, at constant current density (**D_k**=50×10^{-4} kA/m^2) coatings tendency to brittle fracture is reduced, since the critical load (**P_{cr}**), which begins when a brittle fracture of the coating increases from 210 to 320 (N). This is confirmed by the fact that the work spent on plastic (**A_p**) and elastic-plastic deformation of iron - nickel coatings (Table 4) constitute 147×10^{-3}÷551×10^{-3} (N×mm) and 609×10^{-3} ÷1194×10^{-3} (N×mm) and significantly higher than in the previous case (Table 2) respectively 65,9×10^{-3} ÷144,6×10^{-3} (N×mm) and 27479×10^{-3}÷358,8×10^{-3} (N×mm). This proves that a higher amount of plastic (**A_p**) and elastoplastic work associated with the preparation of the beginning of brittle fracture of composite iron - nickel coatings.

Comparing the experimental data it can be argued that the onset of brittle fracture of composite iron - nickel coatings can be determined as much by measuring the depth of the elastic-plastic indentation (N) diamond spherical indenter, elastoplastic characteristics (**h_e; h_p; h; A_e; A_p; A**), the critical load, the beginning of brittle fracture (**P_{cr}**), the critical stress (**H_{hcr}**; **H_{dcr}**) iron-nickel coatings. The critical stress can be taken as a criterion for assessing the tendency to brittle fracture coatings.

Study of the influence of electrolysis conditions (**Дк**, **T**) coatings on the tendency to brittle fracture showed that the critical state of coatings occurs at higher current densities (**Дк**) and lower temperature electrolysis (T).

Studies have shown that the maximal values of elastoplastic characteristics (**A_e**; **A_p** ; **A**; **H_h**; **H_d**; **P**; Tables 1 and 2), iron-nickel coatings can be selected to produce coatings obtained under different conditions of the electrolysis (**Дк**, **T**) in terms of their maximum durability. It will significantly reduce the time of the experiments, increasing the amount of research that will significantly extend the effective use of iron-nickel coatings industry.

4. Conclusions

Experimentally found that hardness unrestored (**H_h**), dynamic hardness (**H_d**), the work expended on elastic (**A_e**), plastic (**A_p**), elastoplastic (**A**) deformation and load spherical diamond indenter (**P** at **h** = 6,0 μm) have to change the nature extreme conditions of electrolysis (**Дк**, **T**) for iron-nickel coatings studied, with the proviso that **$P<P_{cr}$**.

Experimentally established the beginning of brittle fracture of iron-nickel coatings on critical load indentation (**P_{cr}**) and unreduced critical hardness (**H_{hcr}**), changes in the conditions of electrolysis (**Дк**, **T**), the critical load indentation (**P_{cr}**) diamond spherical indenter and the critical stress (hardness **H_{hcr}**) can be taken as a criterion for assessing the tendency to brittle fracture coatings.

For the first time experimentally shown that with the beginning of brittle fracture of iron-nickel coatings at **$P = P_{cr}$**, the work expended on elastic (**A_e**), plastic (**A_p**), elastoplastic deformation (**A**), the load on the diamond spherical indenter (**$P = P_{cr}$**) and the indentation depth (**h_p**; **h**) decreases with increasing current density (**Дк**) and reduction temperature of electrolysis (T).

For the first time experimentally shown that with the beginning of brittle fracture of iron-nickel coatings at **$P = P_{cr}$** work expended on elastic (**A_e**), plastic (**A_p**) and elastic-plastic (**A**) deformation significantly increases in value than in (**$P<P_{cr}$**). This proves that the increase of the work spent on the elastic (**A_e**), plastic (**A_p**) and elastic-plastic (**A**) deformation associated with the preparation of the start of the brittle fracture of iron-nickel coatings.

It is found that with increasing current density (**Дк**) and decreasing temperature electrolysis (**T**) increases the propensity of iron-nickel coating to brittle fracture.

For the first time experimentally shown that unrestored critical hardness (**voltage**, **H_{dcr}**), the critical dynamic hardness (**H_{hcr}**), ratio **H_{hcr}/E** and **H_{dcr}/E** have extreme character changes in the conditions of electrolysis (**Дк**, **T**) for the study of iron - nickel coatings. Extreme values and **H_{hcr} H_{dcr}**, relations **H_{hcr}/E** and **H_{dcr}/E** coincide with our earlier recommendations for iron - nickel coatings in terms of ensuring their optimum durability.

Extreme values unreduced hardness (**H_h**), dynamic hardness (**H_d**), the work expended in elastic (**A_e**), plastic (**A_p**) elastic-plastic deformation (**A**) and the indentation load on the diamond spherical indenter (**P**) coincide with our earlier recommendations for iron- nickel coatings in terms of ensuring their optimum durability.

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