FEATURES ELASTO-PLASTIC DEFORMATION AND BRITTLE FRACTURE, ELECTROLYTIC IRON COATINGS

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1. INTRODUCTION

Electrolytic iron coatings are used for hardening and restoring of machine elements in the industry in order to increase their durability. Terms of electrode position have a significant impact on the physical and mechanical properties of the coatings. Knowledge of the physical and mechanical characteristics of composite coatings of iron needed to make informed choices deposition process conditions, depending on the operating conditions of the recovered parts of the work, as well as for strong calculations.

2. GENERAL INFORMATION

Actual problems of the study of physical and mechanical properties of materials in surface and near-surface layers due to the fact that the deformations associated with contact with modern methods of treatment, hardening and the metal connection.

The importance of determining the elasto-plastic characteristics (he, hp, h), the work required for deformation (Ae, the Ap, A), unreduced and dynamic hardness (Hh, Hd), modulus of elasticity (E) coating the critical load indentation diamond spherical indenter, in which begins the process of brittle fracture (Pcr), the ratio of non-reduced and dynamic hardness to elastic modulus (Hh/E, Hd/E), yield strength (σ_f), the true tensile strength (σ_{vtr}), tensile strength (σ_{tr}), toughness (α_n), the extent of material deformation in the contact zone (φ) is invaluable.

An important parameter of the iron composite coating is brittleness. This property of the coatings is undesirable because the increase in brittleness affects important characteristics such as wear resistance [2].

It is known that the brittleness of coatings envy of pretreatment conditions of the substrate and electroplating. It can be caused by the inclusion of hydrogen coverage, surface active substances (surfactants), metals and other foreign particles.

To determine the brittleness of precipitation, it is mainly used a method based on bending of the plate, with the application of the coating layers. Before the appearance of cracks in the sediment, and the angle of bending the plate appreciate the fragility of the coating [2]. In this case, the test results can depend upon the nature of the material and thickness of the substrate plate. Moreover, using this method, researchers have information about the relative brittleness of coatings without the applied voltage necessary for the formation of cracks in the coating. To this end, it was an attempt to use a method of pressing [1-4] allows you to determine the breaking stress. On the fragility of the coating has a significant influence of electrode position conditions: to increase their stiffness (increased current density, decreasing the temperature of the electrolyte) is significantly increased. The electrolyte composition may have a different impact on the considered properties of the coatings.

We present elasto-plastic properties and their tendency to brittle fracture of electrolytic iron coatings obtained from the electrolyte 1 (2, 59). The samples used rollers diameter 30 mm, thickness of 0.5 tmm and a length of 100 mm, which were processed under optimal conditions of grinding. Physical and mechanical properties were determined at the facility for the study of the hardness of materials macro volume equipped with inductive sensor and a differential amplifier, allows you to record the chart indentation diamond spherical indenter and restore print after unloading.

The dynamic hardness (Hd) was determined as the ratio of the total work (A) consumed for elasto-plastic deformation to the deformable volume indentation (V) under load in all studied electrolytic iron coatings.

On the plastic deformation of the coating associated with the preparation of destruction, spent is spending the work (the An).

At present, the theoretical and experimental issues associated with the assessment of the properties of brittle materials indentation of a spherical indenter, well developed [1-10].

Studies [2] have shown that when a spherical indentation gradually increasing the load on the indenter can reach a critical state in which cracks form a ring, with a diameter approximately the same fingerprint from coatings obtained under all conditions of electrolysis. [2] However, the critical condition occurs when the elasto-plastic deformation. Due to the small residual strain coating great difficulties arise when measuring the diameter of the indentation, so it is locked at the boundary contact area. Furthermore, in this case, to form a continuous circumferential crack occurs occurrence of new cracks arbitrary direction [2].

When scratching the critical load was fixed at cracking perpendicular to the direction of movement of the indenter. As with a spherical indentation, brittle fracture occurred in the presence of plastic deformation. Due to fracture during the test, the coatings were formed as separate new cracks located at different angles to the direction of displacement 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 at the critical load is proportional to the radius of the sphere. With increasing current density, the critical state occurs at lower loads. [2]

For comparison, the theoretical and experimental values of the ratio of the critical load slip (Pcr) to the critical load under static indentation (Pst) was used formula derived from the condition that the critical stress upon occurrence of failure in the case of static and dynamic indentation.

$$\frac{\mathrm{P}cr}{\mathrm{P}st} = \frac{1}{(\,1+3Af)^3}\,,$$

where: *Pcr* and *Pst* - critical load, respectively, with scratching and static indentation.
f - coefficient of friction between the indenter and the sample in scratching.

To determine the value but to use the expression:

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

where: μ - Poisson's ratio of coatings.

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

Despite the value of information, which can be determined by pressing, when it is used there are difficulties associated with determining the diameter of the indentation and the beginning of brittle fracture, which affects the elasto-plastic deformation of coatings by immersing the indenter. Furthermore hardness measuring method based on determination of the diameter of the print does not allow to obtain information about the nature of the elastic deformation of the materials. Therefore, to study the hardness of the coatings was used microvolume hardness TKC-1, you can record a chart indentation diamond spherical indenter and restore print after unloading. As the indenter used artificial diamond sphere with a radius of 1 mm.

As a result of measurement of physical and mechanical properties of iron coatings with different loads on the indenter (P) found that when the initial load (up Pcr) ratio $P/\pi\Delta h$ is constant. With further increase of the load, this value increases sharply, indicating a deviation from the mechanical similarity. In the considered pattern is significantly influenced by the conditions of electrolysis. With the increase in the current density of the original violation of laws takes place at lower loads on the indenter (2).

The study of the (hy) elastic and plastic (Hp) features strain coatings showed that the responsibility for the results is the change in the character of elastic deformation, depending on the loading conditions. Regardless of the conditions for obtaining coatings with increasing load on the indenter deformation elastic component coatings increases sharply at first, then it rises slightly (2).

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

Comparing this critical loads with their values determined from observations of the formation of a ring crack, one could argue that the beginning of brittle fracture surfaces can be determined much more accurately measure the depth of indentation and the critical load (Pcr) as to form a ring crack growth is possible starting cracks the formation of new, behind which is difficult to observe. The critical stress can be taken as a criterion for assessing the tendency to brittle fracture surfaces.

3. DISCUSSION OF EXPERIMENTAL STUDIES

Studies have shown that the elasto-plastic properties and the tendency to brittle fracture of electrolytic iron coatings vary with electrolysis conditions (Table 1-5).

With increasing current density (Dk) of $5\text{x}10^{-4}$ to $80\text{x}10^{-4}$ kA/m^2 at a constant temperature

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

Conditions electrolysis		***H_h, N/ mm²***	***H_d, N/ mm²***	***Elasto plastic properties***						***P, N***	***Pcr, N***
$D_к$, x10⁻⁴ кA/m²	***T, ⁰C***			***h_e, µm***	***A_e, N·mm***	***h_p, µm***	***A_p, N·mm***	***h, µm***	***A, N·mm***		
5	40	3505	2694	0.65	47.66	0.35	25.66	1.0	73.32	22.0	200
10	40	3729	2868	0.66	51.48	0.34	26.52	1.0	78.00	23.4	175
20	40	3855	2963	0.67	54.05	0.33	26.62	1.0	80.67	24.2	150
40	40	3220	2451	0.71	47.81	0.29	19.53	1.0	67.34	20.02	120
20	20	2600	1996	0.76	42.93	0.24	13.04	1.0	55.97	16.3	105
20	60	2750	2118	0.55	31.71	0.45	26.97	1.0	57.68	17.3	225

electrolysis (40^0C), the plastic indentation depth (hp) and critical load indentation (Pcr) on the diamond spherical indenter reduced accordingly by 0.35 to 0.29 (µm) and 200 to 120 (N) and the elastic component of penetration depth (hy) increases from 0.65 to 0.71 (µm), total indentation depth (h) is 1.0 µm.

The work expended on elastic (Ae), plastic (Ap), elasto-plastic deformation (A) and unreduced (Hh), dynamic (Hd) hardness iron coatings, the load pressing the diamond spherical indenter (P) are the extreme value with the change of the current density (Dk) from $5x10^{-4}$ to $40x10^{-4}$ kA/m^2 at a constant temperature of electrolysis (40^0C), table 1.

Elasto-plastic deformation and fracture characteristics of electrolytic iron coatings determined for several indentation depth h = (1,0 ÷ 4,0) µm by a known procedure (2).

Providence studies have shown that an increase in the current density of $5x10^{-4}$ to $20x10^{-4}$ kA/m^2 at a constant temperature electrolysis (40^0C) work expended on the deformation of the iron coating increased from $47.66x10^{-5}$ to $54.05x10^{-5}$ (N•mm), the work spent on the plastic deformation (Ap) coatings increased from $25,66x10^{-5}$ to 26,62 $x10^{-5}$ (N•mm), unrestored coating hardness (Hh) increased from 3505 to 3855 (N•mm), the dynamic hardness (Hd) coatings increased from 2694 to 2963 (N•mm), and the load of pressing the diamond spherical indenter (P) is increased from 22 to 24,2(N).

Since ancient increase in current density (Dk) of $20x10^{-4}$ to $40x10^{-4}$ kA/m^2 at a constant temperature electrolysis (40^0C), the work expended on elastic (Ae) coatings increased by deformation $47.81x10^{-5}$ (N•mm) to $54.05x10^{-5}$ (N•mm), the work spent on the plastic deformation (Ap) decreased from 26.62 $x10^{-5}$ to $19.53x10^{-5}$, the work spent on the elastic-plastic deformation of the coating (A) decreased by $80,67x10^{-5}$ to $67,34x10^{-5}$ (N•mm), unrestorationed coating hardness (Hh) decreased from 3855 to 3220 (N/mm^2), the dynamic hardness of the coating (Hd) decreased from 2963 to 2451(N•mm^2) and the load pressing the diamond spherical indenter (p) decreased from 24,2 to 20,02(N).

According to the survey can be seen that the work spent on the elastic (Ae) plastic (Ap) elastic-plastic (A) deformation of coatings not restored (Hh), dynamic (Hd) hardness and the load pressing the diamond spherical indenter (P) with the change of the current density (Dk) at a constant temperature electrolysis (T) from 20^0C to 60^0C (table 1) at a constant current density ($20x10^{-4}$ kA/m^2), the critical load indentation (Pcr) the diamond spherical indenter characterizes the beginning of electrolytic iron brittle plastic component coatings (hp) the depth of indentation and the work spent on the plastic deformation of the coating (Ap), respectively, increased from 105 to 225 (N), from 0.24 to 0.45 (N•mm) and from $13.04x10^{-4}$ to 26.97 $x10^{-4}$ (N•mm), and the elastic component (hy) of penetration depth of a spherical indenter diamond decreased from 0.76 to 0.55 (µm).

The character of changes in the work expended on elastic (Ae), plastic (Ap), elasto-plastic deformation (A) coating and the indentation load (P) of the diamond spherical indenter at a depth of 1.0 microns is also extreme. With increasing temperature (T) of the cell from 20 to 40^0C at a constant current density ($20x10^{-4}$ kA/m^2), work spent on deforming the elastic coating (Ae) is increased by $42,93x10^{-5}$ up to $54,05x10^{-5}$ (N•mm), the work spent on the elasto-plastic deformation of the coating (A) is increased by up to $55,97x10^{-5}$ $80,67x10^{-5}$ (N•mm), unreduced hardness (Hh) coatings increased from 2600 to 3855 (N•mm^2), dynamic hardness (Hd) coatings increased from 1996 to 2693 (N•mm^2), and the indentation load (P) on a spherical diamond indenter is increased from 16.3 to 24.2 (N).

With further increase of the temperature (T) of electrolysis from 40 to 60°C at a constant current density (Dk) 20 $x10^{-4}$ kA/m^2, the work spent on the elasto deformation (Ae) coatings decreased from $80,67x10^{-4}$ to $57,68x10^{-5}$ (N•mm), unreduced hardness (Hh) from 3855 to 2750 ($N{\cdot}mm^2$), the dynamic hardness of the coatings (Hd) decreased from 2963 to 2118 ($N{\cdot}mm^2$) and load indentation (P) on the diamond spherical indenter decreased from 24.2 to 17.3 (H, table 1).

Table 2. Elasto-plastic deformation and fracture characteristics of electrolytic iron coating.

Conditions electrolysis		H_h, N/mm^2	H_d, N/mm^2	*Elasto plastic properties*						P, N	Pcr, N
D_K, $x10^{-4}$ $\kappa A/m^2$	T, ^0C			h_e, µm	A_e, N·mm	h_p, µm	A_p, N·mm	h, µm	A, N·mm		
5	40	3560	2737	1.30	193.6	0.70	104.3	2.0	297.9	44.7	200
10	40	3760	2902	1.32	208.6	0.68	107.4	2.0	316.0	47.4	175
20	40	3920	3012	1.34	219.8	0.66	108.2	2.0	328.0	49.2	150
40	40	3280	2522	1.42	195.0	0.58	179.5	2.0	374.5	41.2	120
20	20	2650	2051	1.52	169.7	0.48	53.6	2.0	223.3	33.5	105
20	60	2800	2155	1.10	129.1	0.90	105.6	2.0	234.7	35.2	225

Table 3. Elasto-plastic deformation and fracture characteristics of electrolytic iron coatings.

Conditions electrolysis		H_h, N/mm^2	H_d, N/mm^2	*Elasto plastic properties*						P, N	Pcr, N
D_K, $x10^{-4}$ $\kappa A/m^2$	T, ^0C			h_e, µm	A_e, N·mm	h_p, µm	A_p, N·mm	h, µm	A, N·mm		
5	40	3620	2784	1.95	443.3	1.05	3.0	682.0	68.2	68.2	200
10	40	3840	2951	1.98	477.2	1.02	3.0	723.0	72.3	72.3	175
20	40	3970	3053	2.01	501.2	0.99	3.0	748.0	74.8	74.8	150
40	40	3330	2559	2.13	445.2	0.87	3.0	627.0	62.7	62.7	120
20	20	2700	2486	2.28	386.8	0.72	3.0	509.0	50.9	50.9	105
20	60	2840	2200	1.67	294.3	1.35	3.0	535.1	53.9	53.9	225

Table 4. Elasto-plastic deformation and fracture characteristics of electrolytic iron coatings.

Conditions electrolysis		*Elasto plastic properties*						H, N/mm^2	Hh, N/mm^2	P, N	Pcr, N
Dk, $x10^{-4}$ kA/m^2	T, ^0C	h_e, µm	Ae $x10^{-5}$, Hmm	hp, µm	Ap $x10^{-5}$, Hmm	h, µm	A, $x10^{-5}$, Hmm				
5	40	2,60	800,8	1,40	431,2	4,0	1232	2829	3680	92,4	200
10	40	2,64	862,4	1,36	444,3	4,0	1306,7	3000	3900	98	175
20	40	2,68	904,1	1,32	445,3	4,0	1349,4	3098	4030	101,2	150
40	40	2,84	803,7	1,26	356,6	4,0	1160,3	2599	3380	89,9	120
20	20	3,04	861,3	0,96	245,1	4,0	1106,4	2345	3050	76,6	105
20	60	3,20	530,3	1,80	453,8	4,0	964,1	2213	2880	72,3	225

With the change of penetration depth (h) of the diamond spherical indenter electrolytic iron coatings behavior of the stored elasto-plastic deformation (table 2-4), only to change the indentation depth, the work spent on the elastic and plastic deformation, unrestored (Nh), dynamic (Hd) Hardness and the indentation load (P) on the diamond spherical indenter.

The study of the effect of the current density (Dk) and the electrolysis temperature (T) of electrolytic iron propensity to brittle fracture surfaces showed that, with increasing current density (Dk) of $40x10^{-4}$ up to $5x10^{-4}$ kA/m^2 at a constant temperature of electrolysis ($T=40^0C$) critical load pressing the diamond spherical indenter (Pcr) is reduced from 200 to 120 (N), which indicates the increasing tendency of electrolytic iron coating brittle fracture (table 5).

With increasing temperature, the electrolysis of 20 to 60 seconds at a constant current density ($20x10^{-4}$ kA/m^2), the critical load (Pcr) pressing the diamond spherical indenter increases from 105 to 225 (H), indicating that the decrease in inclination of electrolytic iron coatings brittle fracture.

Table 5. Elasto-plastic properties of electrolytic iron coatings in a critical state (early brittle fracture).

Conditions electrolysis		***Elasto plastic properties***				***V, $x10^{-5}$ mm^3***	***Pcr, N***	***Hh_{cr}, N/mm^2***	***Hd_{cr}, N/mm^2***	***E, $x10^{-5}$ N/mm^2***	***Hh_{cr}/E***	***Hd_{cr}/E***
Dk, $x10^{-4}$ kA/m^2	***T, ^0C***	***Ae $x10^{-5}$, Hmm***	***Ap $x10^{-5}$, Hmm***	***h, μm***	***A, $x10^{-5}$, Hmm***							
5	40	800,8	431,2	4,0	1232	18,10	200	3981	2997	1,95	0,0204	0,0151
10	40	862,4	444,3	4,0	1306,7	12,20	175	4347	3066	1,85	0,0235	0,0168
20	40	904,1	445,3	4,0	1349,4	9,08	150	6188	3194	1,75	0,0354	0,0183
40	40	803,7	356,6	4,0	1160,3	8,5	120	5028	2700	1,60	0,0314	0,0169
20	20	861,3	245,1	4,0	1106,4	8,5	105	3498	2600	1,50	0,0269	0,0113
20	60	530,3	453,8	4,0	964,1	34,37	225	6022	2400	2,10	0,0287	0,0124

It causes great interest to determine the beginning of the destruction of the fragile iron coatings in the test indentation. For most of the materials of the theoretical limit strength at shear Gmax. This is due to the fact that the sliding connection between atoms perpendicular to the sliding plane periodically reversed. The degree of recovery of these connections and more flexibility. Unrestored bond equivalent to the appearance of new elementary surface, the creation of which is spent on the job. From this point of view, we consider the change elasto-plastic properties of electrolytic iron coatings at the beginning of brittle fracture surfaces (Pcr, table 5).

With increasing current density (Dk) of $5x10^{-4}$ to $40x10^{-4}$ kA/m^2 at a constant temperature electrolysis (40^0C), elasto-plastic properties (Ae, Ap, h, A) decreased respectively by $35300x10^{-5}$ to $15200x10^{-5}$ (N•mm) from $1800x10^{-5}$ to $7260x10^{-5}$ (N•mm), from 8.0 to 5,6 (μm) and from $53300x10^{-5}$ to $22400x10^{-5}$ (N•mm). The volume of prints (V) at the load also reduced by up $18.1x10^{-5}$ to $8.5x10^{-5}$(mm^3).

The results obtained show that the process of electrolytic iron brittle coatings started (table 5). Work spent at elastic (Ae), plastic and elasto-plastic (Ap) deformation of the iron coatings with critical indentation load (Pcr) significantly higher (table 5) than in the previous cases (table 1-4). This shows that the elastic, plastic and general deformation of electrolytic iron coatings spent considerably more work (Ae; Ap; A), which is connected with the beginning of brittle fracture surfaces.

With increasing current density (Dk) of $5x10^{-4}$ to $40x10^{-4}$ kA/m^2, at a constant temperature electrolysis (40^0C), unrestored critical hardness (Hh_{cr}), a critical dynamic hardness (Hd_{cr}), and their relationship Hh_{cr}/E have both before the extreme nature (table 5). Since the beginning of the achievements of brittle fracture electrolytic iron coatings under various conditions of the electrolysis (Dk, T) critical load varies from 105 to 225 (N) and the indentation depth of the diamond spherical indenter (h) also varies from 5.6 to 11.0 (μm).

Studies have shown that an increase in current density (Dk) of $5x10^{-4}$ to $20x10^{-4}$ kA/m^2, at a constant temperature electrolysis (40^0C) unrestored critical hardness (Hh_{cr}) increased from 3981 to 6188 (N/mm^2), the dynamic critical hardness (Hd_{cr}) increased from 2997 to 3194 (N/mm^2), and the ratio Hh_{cr}/E and Hd_{cr}/E increased, respectively, from 0.0204 to 0.0354 and from 0.0151 to further 0,0183. Current density of $20x10^{-4}$ to $40x10^{-4}$ kA/m^2, at a constant current density (40^0C) unrestored critical hardness (Hhcr) decreased from 6188 to 5028 (N/mm^2), the critical dynamic hardness (Hd_{cr}) decreased from 3194 to 2700 (N/mm^2) and the ratio of Hh_{cr}/E and Hd_{cr}/E of 0.354 to 0.314 and from 0.354 to 0.314 and from 0.183 to 0.169.

With increasing temperature, the electrolysis of 20 to 60^0C (see table 5) at a constant current density $20x10^{-4}$ kA/m^2, the critical load indentation (Pcr) characterizing the beginning brittle iron coatings, elasto-plastic properties (Ae; Ap; h; A) increases respectively from 105 to 225 (N) from $16800x10^{-5}$ to $44600x10^{-5}$ (N/mm^2), from $5300x10^{-5}$ to $37900x10^{-5}$ (N/mm^2), from 8.5 to 34.37 (μm), and from $22100x10^{-5}$ to $82500x10^{-5}$ (N/mm^2).

With increasing temperature electrolysis (T) from 20 to 40^0C, at a constant current density $20x10^{-4}$ kA/m^2 unrestored critical hardness (Hh_{cr}) increased from 3498 to 6188 (N/mm^2), the critical dynamic hardness (Hd_{cr}) increased from 2600 to 3194 (N/mm^2), the ratio Hh_{cr}/E and Hd_{cr}/E increased, respectively, from 0.0269 to 0.0354 and from 0.0113 to 0.0183 and volume the footprint volume under load (V) decreased from $8,5x10^{-5}$ to $9,08x10^{-5}$ (N/mm^2).

With further increase in temperature electrolysis from 40 to 60^0C at a constant current density (Dk) $20x10^{-4}$ kA/m^2 unrestored critical hardness (Hh_{cr}) decreased from 6188 to 6022 (N/mm^2), the dynamic critical hardness (Hd_{cr}) decreased from 3194 to 2400 (N/mm^2), the ratio Hh_{cr}/E and Hd_{cr}/E decreased respectively from

0.0354 to 0.0287, and from 0.0183 to 0.0124, and volume the fingerprint volume under load (V) increased from 9.08 to 34.37 (N/mm^2). In this case, the results obtained confirm the beginning of the destruction of the fragile iron coatings (Table 5).

With increasing temperature electrolysis (T) of 20 to 60^0C at a constant current density ($20x10^{-4}$ kA/m^2) coating the propensity to brittle fracture is reduced, since the critical load (Pcr) at which brittle fracture starts coating increases from 105 to 225. This is confirmed and in that the work expended on the elastic and plastic deformation of the overall coating (table 5) is significantly higher than in the previous cases (see table 1-4). This proves that the higher elastic (Ae), plastic (Ap) and elasto-plastic work (A) associated with the start of electrolysis of iron brittle coatings.

Comparing the experimental data may claim (5-11), which begin the process of brittle iron coatings can be determined by measuring the elasto-plastic indentation depth of the diamond spherical indenter, elasto-plastic characteristics (he; hp; h; Ae; Ap; A) the critical indentation load (Pcr), the beginning of brittle fracture, critical stress iron coatings (Hh_{cr}; Hd_{cr}). The critical voltage (Nh_{cr}; Hd_{cr}) can be taken as a criterion for assessing the tendency to brittle fracture surfaces.

The study of the influence of electrolysis conditions (Dk, T) on the tendency to brittle fracture surfaces showed that the critical condition of the coating occurs at higher current densities (Dk) and less than the electrolysis temperature (T).

Studies have shown that the maximum values of elasto-plastic characteristics (Ae; Ap; A; Hh; P, table 1-4) iron coatings can make a selection of coatings obtained under different conditions of the electrolysis (Dk, T) in terms of maximum resistance to wear.

This 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. CONCLUSION

It was established experimentally that the unreduced hardness dynamic hardness (Hh), the dynamic hardness (Hd), the work expended on elastic (Ae), plastic (Ap), elasto-plastic (A) and the load deformation of the diamond spherical indenter (at h=1-4 μm) have an extreme character with a change in the conditions of the electrolysis (Dk, T) for the study of iron coatings, provided that (P<Pcr).

Experimentally established the beginning of the destruction of the iron coating on the critical load extrusion (Pcr) and recovery of critical hardness (Hh_{cr}), with a change in the conditions of the electrolysis (Dk, T). Critical load indentation (Pcr) diamond spherical indenter and the critical stress (hardness Hhcp) can be taken as a criterion for assessing the tendency to brittle fracture surfaces.

It was established experimentally that since the beginning of brittle iron coatings (at P=Pcr) work expended on elastic (Ae), plastic (Ap), elasto-plastic deformation (A), the load on the diamond spherical indenter (P = Pcr) and the depth of the indentation (hp; h) decreases with increasing current density (Dk) and the decrease in the temperature of electrolysis (T).

It was established experimentally that with the beginning of brittle iron coating (at P=Pcr) work expended on elastic (Ae), plastic (Ap) and elasto-plastic (A) strain significantly increased in value than when (P<Pcr). This shows that the increase in the work expended on elastic (Ae), plastic (Ap) and elasto-plastic (A) of the strain associated with the beginning of the brittle iron coatings.

It is found that with increasing the current density (Dk) and the decrease in the electrolysis temperature (T) increases the tendency of iron coatings to brittle fracture.

It was established experimentally that the critical unreduced hardness (voltage Hdkp), a critical dynamic hardness (Hdkp), the ratio Hhkp/E and Hdkp/E has an extreme character with a change in the conditions of the electrolysis (Dk, T) for the study of iron coatings. Extreme values Hhcp, Hdcp, relations Hhkp/E and Hdkp/E coincide with our earlier recommendation for iron coatings in terms of optimum durability.

Extreme values are reduced hardness (Hh), dynamic hardness (Hd), the work expended on elastic (Ae), plastic (Ap), elasto-plastic deformation (A) and the load indentation on diamond spherical indenter (P) coincide with our earlier recommendations. Coatings for railways in terms of ensuring their optimum durability.

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