ELASTO-PLASTIC PROPERTIES AND POROSITY CHARACTERISTICS OF DEFINE RAILWAY ELECTROLYTIC COATINGS

[1]PhD, professor Vasile Javgureanu, [1]PhD, associate professor Pavel Gordelenco, [2]Lecturer Diana Bors
[1]Technical University of Moldova, Chisinau
[2]Technical College, Chisinau

1. INTRODUCTION

The paper presents some features of the elasto-plastic deformation (Ae, Ap, A, Hh, H, P) and the porosity characteristics (K, ρ) of electrolytic iron coatings on various indentation depth of the diamond spherical indenter (1-6μm). It is found that the parameters (Ae, Ap, A, Hh, H and P) have an extreme character, which coincide with the guidelines for choosing the electrolysis conditions for optimal composition electrolytic iron coatings in terms of wear resistance.

The experimentally determined coefficient takes into account the degree of compaction of the material (k) and porosity (ρ) of electrolytic iron coatings with the change of conditions of electrolysis (Dk, T).

2. GENERAL INFORMATION

When electrodepositing iron coatings which included a large number of foreign particles significantly affect the structure of residues and, consequently, their physical and mechanical properties. High-voltage internal coatings depends on the characteristics electro crystallization precipitation. These features are the main reason for defining the properties of the coatings such as hardness, porosity, fragility, fatigue resistance of coatings. [1]

Under the influence of the internal stresses in the coatings appear porosity which can be divided into three groups:

- macropores occur depending on the structure of the coatings which is formed under the influence of electrolysis conditions;
- micropores arise depending on the coating structure which is influenced by the conditions of the electrolysis;
- channel porosity; type (network of cracks) arising due to the presence of large internal stresses.

In all cases an increase of internal stresses in the coating causes an increase in porosity [1]. Education has channel porosity; type coatings contributes to higher wear resistance of coatings with their work in the boundary lubrication conditions.

The electrolysis conditions have a significant impact on the density of the coating [1]. This is due to the change in porosity sediments. Perhaps, however vary within wide limits and elastic characteristics of the coatings.

Drinking Hh/H is almost independent of the nature of the pressure distribution in print, and is determined only by the medium pressure, normalized to the resulted P in the elastic modulus.

Analysis of elastic deformations in typo, followed by calculating the ratio of reduced and unreduced hardness is important for the study and the subsequent development of experimental methods of testing kinetic hardness and micro hardness.

Drinking Hh/H - important experimental parameter and its deviation from the calculated value may characterize a necessary measure to materials and hardening of the surface layers and coatings, as porosity. Analysis of this relationship a number of papers [2], which is also in the presence of two elastic displacement of the contacting bodies (one of them is the indenter) applied load is distributed over the area of the plastic print.

To assess the porosity of the surface layers of the material the technique of estimating the degree of porosity of the material for his seal indentation. The seal appears to change the height of the print roll around and leads to a reduction ratio Hh/H. Therefore to quantify and seals need to measure both hardness (Hh - unreduced hardness, H - restored hardness).

In the absence of material porosity ratio Hh/H in the first approximation, to be constant.

Due to the high localization of the local plastic deformation test with continuous recording of process parameters pressing spherical indenter can give more information than the tensile test at preserving its main advantage as a method of non-destructive and express control of material properties.

One of the defining characteristics of the powder coating materials is their porosity (ρ), touted as the overall level and nature of the pore size distribution. The latter is very important because the pores being stress raisers, reduce the plastic properties of the material.

The influence of porosity on the process of indentation is dependent on the size of the fingerprint. If the pore size and the distance between them is greater than the print size, the probability of entering the pores in the print zone, and hence the local fluctuation of density of the material is subject to static laws.

If the print size significantly greater than the distance between the pores, the print area is saved middle static density of the material, depending on the total porosity of the material.

The total porosity of the indentation determines the change in the modulus of elasticity E and the relationship Hh/H.

The porosity of the material is determined by the formula:

$$\rho = 2(1 - \kappa);$$

where:

k - factor takes into account the degree of compaction of the material;

$$\kappa = (H_h/H)^{0,5}$$

where:

Hh- unreduced hardness of the material;

H - restored hardness of the material;

Meaning of E and Hh/H depend on pore shape. Offset pores according Krivoglaz give a lower modulus of elasticity E. In addition, they are easier to heal in the plastic zone under imprinted as spherical pores to heal a higher degree of hydrostatic compression. In connection with these flattened pores easily compacted, and thus have a lower ratio Hh/H ratio and higher strain hardening.

We present elastoplastic properties and porosity characteristics of iron coatings produced from the electrolysis of 1 [1, p.59]. The samples of 30 mm diameter rollers, coating thickness 0.5 mm and a length of 100mm, 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, you can record a chart indentation diamond spherical indenter and restore print after unloading [1].

3. DISCUSSION OF THE EXPERIMENTAL STUDY

Studies have shown that the studied elastoplastic properties and porosity characteristics electrolytic iron coatings vary with the conditions of electrolysis (table 1-6).

Table 1. Elastoplastic properties and porosity of electrolytic iron coatings (h=1 μм).

Conditions electrolysis		*Elastoplastic properties*						*H, N/mm^2*	*Hh, N/mm^2*	*Hh/H*	*E, N/mm^2*	*P, N*	*K*	*ρ*
Dк, x10^{-4} кA/m^2	*T, ^{0}C*	*he, μм*	*Ae, x10^{-4} N•mm*	*hp, μм*	*Ap, x10^{-5} Nmm*	*h, μм*	*A, x10^{-4} Nmm*							
5	40	0,65	47,66	0,35	25,66	1,0	73,30	10009	3505	0,350	1,95	22,00	0,59	0,82
10	40	0,66	51,48	0,34	26,62	1,0	78,00	11437	3729	0,330	1,85	23,40	0,57	0,86
20	40	0,67	54,05	0,33	26,62	1,0	80,66	13288	3855	0,290	1,75	24,20	0,54	0,92
40	40	0,71	47,81	0,29	19,53	1,0	67,33	10993	3220	0,290	1,60	20,02	0,54	0,92
20	20	0,76	42,93	0,24	13,04	1,0	54,33	10815	2600	0,240	1,30	16,30	0,49	1,02
20	60	0,55	31,71	0,45	25,97	1,0	57,66	6079	2750	0,245	2,10	17,30	0,67	0,66

Table 2. Elastoplastic properties and porosity of electrolytic iron coatings (h=2 μм).

Conditions electrolysis		*Elastoplastic properties*						*H, N/mm^2*	*Hh, N/mm^2*	*Hh/H*	*E, N/mm^2*	*P, N*	*K*	*ρ*
Dк, x10^{-4} кA/m^2	*T, ^{0}C*	*he, μм*	*Ae, x10^{-4} Nmm*	*hp, μм*	*Ap, x10^{-5} Nmm*	*h, μм*	*A, x10^{-4} Nmm*							
5	40	1,30	193,6	0,70	104,3	2,0	298	10168	3560	0,350	1,95	44,7	0,590	0,820
10	40	1,32	208,6	0,68	107,4	2,0	316	11101	3760	0,339	1,85	47,4	0,580	0,840
20	40	1,34	219,8	0,66	108,2	2,0	328	11870	3920	0,233	1,75	49,2	0,570	0,860
40	40	1,42	195,1	0,58	79,5	2,0	274,7	11312	3280	0,290	1,60	41,2	0,538	0,924
20	20	1,52	169,7	0,48	53,6	2,0	285,3	11115	2650	0,238	1,30	33,5	0,448	1,104
20	60	1,10	129,1	0,90	105,6	2,0	234,6	6228	2800	0,450	2,10	35,2	0,670	0,660

Table 3. Elastoplastic properties and porosity of electrolytic iron coatings (h=3 μм).

Conditions electrolysis		***Elastoplastic properties***						***H, N/mm^2***	***Hh, N/mm^2***	***Hh/H***	***E, N/ mm^2***	***P, N***	***К***	***ρ***
$D_к$, x10^{-4} кA/m^2	***T, ^{0}C***	***he, μм***	***Ae, x10^{-4} Nmm***	***hp, μм***	***Ap, x10^{-5} Nmm***	***h, μм***	***A, x10^{-4} Nmm***							
5	40	1,95	44,33	1,05	23,87	3,0	68,20	10343	3620	0,35	1,95	68,2	0,592	0,816
10	40	1,98	47,72	1,02	24,58	3,0	72,30	11286	3840	0,34	1,85	72,3	0,583	0,834
20	40	2,01	50,12	0,99	24,68	3,0	74,80	12032	3970	0,33	1,75	74,8	0,574	0,852
40	40	2,13	44,52	0,87	18,18	3,0	62,70	11475	3330	0,29	1,60	62,7	0,539	0,922
20	20	2,28	38,68	0,72	12,22	3,0	50,90	11256	2700	0,24	1,30	50,90	0,490	1,020
20	60	1,67	29,43	1,35	24,08	3,0	53,50	6310	2840	0,45	2,10	53,90	0,671	0,658

Table 4. Elastoplastic properties and porosity of electrolytic iron coatings (h=4 μм).

Conditions electrolysis		***Elastoplastic properties***						***H, N/mm^2***	***Hh, N/mm^2***	***Hh/H***	***E, N/ mm^2***	***P, N***	***К***	***ρ***
$D_к$, x10^{-4} кA/m^2	***T, ^{0}C***	***he, μм***	***Ae, x10^{-4} Nmm***	***hp, μм***	***Ap, x10^{-5} Nmm***	***h, μм***	***A, x10^{-4} Nmm***							
5	40	2,60	80,08	1,40	43,12	4,0	123,2	10509	3680	0,350	1,95	92,4	0,592	0,816
10	40	2,64	86,24	1,36	44,43	4,0	130,7	11474	3900	0,34	1,85	98,0	0,583	0,834
20	40	2,68	90,41	1,32	44,53	4,0	134,9	12208	4030	0,33	1,75	101,2	0,575	0,850
40	40	2,04	80,37	1,26	35,66	4,0	113,2	10707	3380	0,31	1,60	84,0	0,560	0,880
20	20	3,04	86,13	0,96	24,51	4,0	102,1	12705	3050	0,24	1,30	76,6	0,490	1,02
20	60	2,20	53,03	1,80	43,38	4,0	96,4	6396	2880	0,45	2,10	72,3	0,671	0,658

With increasing current density (Dk) of 5x10^{-4} to 40x10^{-4} kA/m^2 at a constant temperature electrolysis (40°C) plastic component (hp), spherical indentation depth of a diamond indenter, the ratio (Hh/H), the coefficient takes into account the degree of compaction of the material (K) and modulus of elasticity (E) are reduced respectively from 0.35 to 0.29 (μm), from 0.350 to 0.290, from 0.59 to 0.54 and from 19500 to 1600 (N/mm^2), and the elastic component (hy) of penetration depth and porosity of electrolytic iron coating increases, respectively, from 0.65 to 0.71 (μm) and from 0.82 to 0.92. Overall, while the depth was 1 μm time (h). The work expended on elastic (Ae), plastic (Ap), the total deformation (A), restored the hardness (H) is not restored hardness (Hh) and 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), electrolysis at a constant temperature (40°C) (tables 1-5).

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°C), the work spent on the elastic deformation of the iron coating (Ae), increased by 47.66x10^{-5} to 54.05x10^{-5} (N*mm) work spent on the plastic deformation of the coating increased from 25.66x10^{-5} to 26.62x10^{-5} (H·mm), and the total work spent on the elasto-plastic deformation of the coating increased from 73.3x10^{-5} to 80.66x10^{-5} (H·mm). With further increase of the current density of up 20x10^{-4} to 40x10^{-4} (kA/m^2) at a constant temperature electrolysis (40°C) the work spent on the elasto-plastic deformation of the coating decreased by 54.05x10^{-5} to 47.81x10^{-5} (H·mm) the work spent on the plastic deformation of the coating decreased by 26.62x10^{-5} to 19.53x10^{-5} (H·mm), and the total work spent on the elasto-plastic deformation of the coating decreased by 80.66x10^{-5} to 67.33x10^{-5} (H·mm). From the results of research it is clear that the work spent on the elastic (Ae), plastic (Ap), and elastic-plastic deformation (A) iron coatings have an extreme character with a change in the current density (Dk) at a constant temperature electrolysis (T,^{0}C). The nature of the changes restored (H), unreduced (Hh) hardness and indentation load (P) of the diamond spherical indenter at different penetration depth (1-6) microns to increase the current density of up to 5x10^{-4} - 40x10^{-5} (kA/m^2), at a constant temperature electrolysis (40^{o}C) have extreme character
(table 1-6).

With increasing current from 5x10^{-4} to 50x10^{-5} (kA/m^2), at a constant temperature electrolysis (40^{o}C) restored the hardness (H) increased from 10009 to 13288 (N/mm^2), unreduced hardness (Hh) has increased from 3505 yes 3855 (N/mm^2) and a load of pressing the diamond spherical indenter has increased from 22 to 24.2 (N).

Table 5. Elastoplastic properties and porosity of electrolytic iron coatings (h=5 μм).

Conditions electrolysis		*Elastoplastic properties*						*H, N/ mm^2*	*Hh, N/mm^2*	*Hh/H*	*E, N/ mm^2*	*P, N*	*К*	*ρ*
Dк, x10^{-4} кА/ m^2	*T, ^{0}C*	*he, μм*	*Ae, x10^{-4} Nmm*	*hp, μм*	*Ap, x10^{-5} Nmm*	*h, μм*	*A, x10^{-4} Nmm*							
5	40	3,25	126,56	1,75	68,31	5,0	194,87	10655	3730	0,350	1,95	117,1	0,592	0,816
10	40	3,30	136,73	1,70	70,44	5,0	207,17	11643	3960	0,340	1,85	124,3	0,583	0,834
20	40	3,35	143,38	1,65	70,66	5,0	214,00	12551	4090	0,330	1,75	128,4	0,571	0,858
40	40	3,55	140,46	1,45	57,37	5,0	196,66	13035	3780	0,290	1,60	118,7	0,539	0,922
20	20	-	-	-	-	-	-	-	-	-	1,30	-	-	-
20	60	2,75	84,06	2,25	68,38	5,0	152,83	6573	2920	0,440	2,10	91,7	0,667	0,666

Table 6. Elastoplastic properties and porosity of electrolytic iron coatings (h=6 μм).

Conditions electrolysis		*Elastoplastic properties*						*H, N/ mm^2*	*Hh, N/mm^2*	*Hh/H*	*E, N/ mm^2*	*P, N*	*К*	*ρ*
Dк, x10^{-4} кА/ m^2	*T, ^{0}C*	*he, μм*	*Ae, x10^{-4} Nmm*	*hp, μм*	*Ap, x10^{-5} Nmm*	*h, μм*	*A, x10^{-4} Nmm*							
5	40	3,90	184,73	2,10	99,47	6,0	284,2	10775	3770	0,350	1,95	142,1	0,592	0,816
10	40	3,96	199,98	2,04	103,02	6,0	303,0	11289	4020	0,340	1,85	151,5	0,582	0,836
20	40	4,02	224,32	1,98	110,48	6,0	334,8	13463	4500	0,330	1,75	167,4	0,578	0,844
40	40	-	-	-	-	-	-	-	-	-	-	-	-	-
20	20	-	-	-	-	-	-	-	-	-	-	-	-	-
20	60	3,30	122,65	2,70	100,35	6,0	223,0	6576	2960	0,450	2,10	111,5	0,671	0,658

With further increase of the current density from 20x10^{-4} to 40x10^{-5} (kA/m^2), at a constant temperature electrolysis (40°C), restored the hardness (H) decreased from 13288 to 10993 (N/mm^2), unreduced hardness decreased from 3855 to 3220 (N/mm^2) and the indentation load on the diamond spherical indenter (R) decreased from 24,2 to 20,02 (N).

With increasing temperature electrolysis (table 1-6) at a constant current density (20x10^{-4} kA/m^2), up from 20°C to 60°C the plastic component (hp) penetration depth, the ratio of Hh/H modulus of elasticity (E) coefficient taking into account the degree of compaction of the material (K) increases, respectively (table 1-6) from 0.24 to 0,45 (μm), from 0.240 to 0.452, from 13000 to 21000 (N/mm^2) and from 0.49 to 0.67.

The character of changes in the work expended to another (Ae), plastic (Ap) and elastoplastic (A) deformation of electrolytic iron coating with temperature electrolysis of 20°C to 60°C at a constant current density (20x10^{-4} kA/m^2) has an extreme character for all depths spherical diamond indenter indentation (h from 1 to 6 μm), table 1-6).

With the increase of electrolysis temperature of 20°C to 40°C at a constant current density (20x10^{-4} kA/m^2) robot spent on elastic (Ae), plastic (Ap) and elasto-plastic (A), respectively, of the deformation increased from 54.05x10^{-5} to 42.93x10^{-5} (N·mm), up from 13.05x10^{-5} 26.62x10^{-5} (N·mm), and from 54.33x10^{-5} to 80,66x10^{-5} (N·mm).

With further increase of the electrolysis temperature of 40 to 60°C at a constant current density (20x10^{-4} kA/m^2), the work expended on elastic (Ae), plastic (Ap) and elasto-plastic deformation of electrolytic iron coatings increased respectively by 54.05x10^{-5} up 31.71 x10^{-5} (N/mm^2), from 26.02x10^{-5} to 25.97x10^{-5} (N·mm) and from 80.66x10^{-5} to 57.66x10^{-5} (N·mm).

Character changes unreduced hardness (Hh), reduced (H), the hardness and load of pressing the diamond spherical indenter (P) for all penetration depth of 1 to 6 microns with increasing temperature electrolysis of from 20°C to 60°C with constant toke 20x10^{-4} (kA/m^2) also has an extreme character. With increasing temperature electrolysis from 20°C to 40°C at a constant current density 20x10^{-4} (kA/m^2) is not restored hardness increased from 2600 to 3855 (N/mm^2) from 10815 to 13288 (N/mm^2) and a load of pressing the diamond spherical indenter increased from 16.3 to 24.2 (N). With further increase in temperature electrolysis from 40°C to 60°C at a constant current density (20x10^{-4} kA/m^2), unreduced hardness decreased from 3855 to 2750 (N/mm^2), from 13288 to 6079

(N/mm^2) and the load indentation diamond spherical indenter has decreased from 24.2 to 17.3 (N).

Studies have shown that the unreduced hardness (H), the work expended on elastic (Ae), plastic (Ap), elasto-plastic (A) deformed, the load on the diamond spherical indenter (with all the indentation depth of 1 to 6 μm) have an extreme character with change in the conditions of the electrolysis (Dk, T) for the study of electrolytic iron coatings and coincide with the earlier recommendations in terms of their optimal wear resistance.

Experimentally proved (table 1-6), the ratio Hh/H, K - factor takes into account the degree of compaction of electrolytic iron coatings and elastic modulus E decreases with increasing current density (Dk) and a decrease in temperature electrolysis (T).

With increasing current density (Dk) and the decrease in the electrolysis temperature (T) increases the porosity of electrolytic iron coatings (tables 1-6). This proves that the conditions of the electrolysis (Dk, T) has a significant impact elastoplastic properties, density and porosity of electrolytic iron coatings.

4. CONCLUSION

It is experimentally established that the recovered hardness (H) unreduced hardness (Hh), the work expended on elastic (Ae), plastic (Ap), elasto-plastic deformation (A) and the load (P) is not the diamond spherical indenter (with all the indentation depth of 1 to 6 microns) are the extreme nature of the changes to the conditions of the electrolysis (Dk, T) for the study of electrical iron coatings.

The experimentally determined coefficient takes into account the degree of compaction of electrolytic iron coatings (K) and porosity (ρ) with a change in the conditions of the electrolysis (Dk, T);

It was established experimentally that an increase in current density (Dk) and a decrease in temperature (T) of the electrolysis for electrolytic iron coatings coefficient taking into account the degree of compaction of the material (K) is decreased, and coating porosity increases (ρ).

Experimental (maximum) value of the recovered hardness (H), not reduced hardness (Hh) work expended on elastic (Ae), plastic (Ap) elasto-plastic deformation (A) of the load on the diamond spherical indenter (P) coincide with the received recommendations for electrometric iron coatings in terms of ensuring their optimum wear resistance.

Physical and mechanical properties (Ae; Ap; A; Hh; P) of electrolytic iron coatings have a good correlation with the intensity of wear of these coatings.

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