SOME ELASTOPLASTICALLY DEFORMATION AND FAILURE COMPOSITE IRON - NICKEL COATINGS

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1. INTRODUCTION

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

Electrolytic wear-resistant coatings are widely used for hardening and restoration parts in the industry in order to increase their longevity.

Electro deposition conditions have a significant impact on the physical and mechanical properties of wear-resistant galvanized coating. 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].

1.2. Overview

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 micro hardness opens up new possibilities for the determination of physical and mechanical properties and fracture toughness of electrolytic plating coating [1-3].

In the robot are some features elastoplastic deformation and brittle fracture iron-nickel composite coatings obtained from electrolyte 4 [2, p.59]. The samples used rollers with diameter 30mm, thickness of the coating 0.5 mm and a length of 100mm, which were processed under optimal grinding.

The importance of identifying the characteristics of elastic-plastic (he, hp, h) required for robot deformation (Ae, Ap, A), not restored and dynamic hardness (Hh, Hd) modulus (E), the critical load indentation diamond spherical indenter with a start brittle fracture (Pcr), the ratio of non-reduced and dynamic hardness to elastic modulus (Hh/E, Hd/E), yield strength (σ_T), the true tensile strength (SB), tensile strength (σ_b), yield strength ($\sigma_{0,2}$) toughness (e_H), the degree of deformation of the material in the contact zone (ψ) is invaluable.

Physic mechanical characteristics were determined at the facility for the study of the hardness of materials in macro volume equipped with an inductive sensor and a differential amplifier allows you to record chart indentation diamond spherical indenter and indentation recovery after removal of the load [2].

Table 1. Physical and mechanical properties of Fe-Ni composite coatings.

Electrolysis conditions		**Work expended on the deformation of coatings**			***Hh, H/mm²* *h=2 µm***	***Hd, H/mm²***	***P, H***	***Pcr, H***	***E ×10⁻⁴, H/mm²***	***Hh/E***	***Hd/E***
Dk, ×10⁻⁴ кA/m²	***T, ⁰C***	***Ay, H× mm***	***An, H× mm***	***A, H× 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

Table 2. Work expended on the deformation of coatings.

Electrolysis conditions		Work expended on the deformation of coatings			*Hh H/mm²* *h=2μm*	*Hd H/mm²*	*P, H*	*Pcr, H*	*E×10⁴ H/mm²*	*Hh/E*	*Hd/E*
Dk, ×10⁻⁴ кA/m²	*T, ⁰C*	*Ae, H mm*	*Ap H mm*	*A H 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

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

2. DISCUSSION OF EXPERIMENTAL STUDIES

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].

With increasing current density (Dk) of 5 x 10^{-4} to $80x10^{-4}$ kA/m^2 electrolysis at a constant temperature (40°C), the critical load (Pcr) and the iron-nickel coatings modulus (E) is reduced accordingly from 350 to 215 (H) and from $21x10^{-4}$ to 17.5×10^{-4} (N/mm^2). Work expended in elastic (Ae), plastic (Ap), unrestored hardness (Hd), dynamic hardness (Ha), 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 $5x10^{-4}$ to $80x10^{-4}$ kA/m^2 to electrolysis at a constant temperature (40°C). Physical and mechanical properties of iron-nickel coatings (Table 1 and 2) determined for one indentation depth (h=2 μm) by a known method [2].

Studies have shown that with increasing current density of $5x10^{-4}$ to $50x10^{-4}$ 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 mm with increasing current density from 5x to 80x (kA/m2), at a constant temperature electrolysis (-40°C) has an extreme character.

With increasing current density of 5x 10^{-4} to $50x10^{-4}$ (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 load on the diamond indentation spherical indenter (P) increased from 45.6 to 56,1 (H). With further increase in current density (D_K) from $50x10^{-4}$ to $80x10^{-4}$ (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 (H/mm^2) and the indentation load on the diamond spherical indenter decreased from 56.1 to 41.7 (H) (table 1).

With increasing temperature electrolysis (T, Table 2) at a constant current density ($D_K = 50x10^{-4}$ 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 elastic modulus of the coating increases, respectively, from 205 to 315 (H) and from 17.1 x 10^4 to 20,5 x10^4 (H/mm^2).

After electrolysis conditions laid out in the deformation coatings Nature of the change work expended in elastic (Ae), plastic (Ap) and elastic-plastic deformation of iron-nickel coatings with temperature electrolysis from 20 to 60°C at a constant current density ($D_K = 50x10^{-4}$ kA/m^2) also has an extreme character. With increasing temperature, the cell from 20 to 40°C at a constant current density ($D_K = 50x10^{-4}$ kA/m^2), the work expended in elastic (Ae), plastic (Ap) and elastic-plastic deformed (A) increased respectively from $21.1x10^{-3}$ to 23.5×10^{-3} (N•mm) from 6.7 x10 3 to 14.8 $x10^{3}$ (N•mm), and from 27.8×10^{-3} to 38.3 $x10^{-3}$ (N•mm). With further increase of the temperature (T) of the cell from 40 to 60°C at a constant current density (D_K = $50x10^{-4}$ 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 $x10^{-3}$ (N•mm) of 14.8×10^{-3} to 13.8 $x10^{-3}$ (N•mm), and from 38.3×10^{-3} to 29.4 $x10^{-3}$ (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 = $50x10^{-4}$ kA/m^2) have also extreme. With increasing temperature electrolysis (T) from 20°C to 40°C at a constant current density (Dk = $50x10^{-4}$ 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 (H). With further increase of the temperature of the cell from 40°C to 60°C at a constant current density (Dk = $50x10^{-4}$ kA/m^2) unreduced 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 (H).

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 electro deposition [2].

C increase in current density (D_K) 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 Pct) 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 (Hhcr) 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 $5x10^{-4}$ to $80x10^{-4}$ (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 = $50x10^{-4}$ kA/m^2), the critical load indentation on diamond spherical indenter is increased from 205 to 315 (H), 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, P_{CR}, 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, An is, 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 x 10^{-4} to $50x10^{-4}$ (kA/m^2) at a constant temperature of electrolysis (40°C) the ratio Hh/E and Hd/E (Table 1), respectively, increases from 17.3×10^{-3} to 23.8×10^{-3} and 11.5×10^{-3} to $15.9x10^{-3}$. With a further increase in current density (Dk) from $50x10^{-4}$ to $80x10^{-4}$ (kA/m^2) at a constant temperature of electrolysis (40°C), the ratio Hh/E and Hd/E accordingly reduced from 23.8×10^{-3} to 3 and $19x10^{-3}$ from 15.9×10^{-3} to 12.7 $x10^{-3}$.

With increasing temperature electrolysis (T) from 20 to 40°C at a constant current density (Dk = $50x10^{-4}$ kA/m^2) ratio Hh/E and Hd/E increases conform to 19.4×10^{-3} to 23.8×10^{-3} and from $13x10^{-3}$ to $15.9x10^{-3}$. With further increase of the electrolysis temperature of 40 to 60°C at a constant current density (Dk = $50x10^{-4}$ kA/m^2) ratio Hh/E and Hd/E accordingly reduced from 23.8×10^{-3} to 17.7×10^{-3} and 15, $9x10^{-3}$ to 11.8×10^{-3}.

3. CONCLUSION

It was established experimentally that the unreduced hardness (Hh), dynamic hardness (Hd) work spent on elastic (Ae), plastic (Ap) elastic-plastic (A) deformation, the load on a spherical diamond indenter (P for h = 2 ***μm***) ratio Hh/E and Hd/E has 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) elastic-plastic deformation (A) load on a spherical diamond indenter (P) ratio Hh/E and Hd/E coincides with those obtained robot us recommendations for iron-nickel coatings in terms of ensuring their optimum durability.

Experimentally established the beginning of brittle fracture of iron-nickel coatings (Pcr, Hhcr) with modified conditions of electrolysis (Dk, T), the critical load (Pcr) indentation on diamond spherical indenter and the critical stress (Hhcr), which can be taken as a criterion for assessing the propensity coatings for brittle fracture.

The method of measuring the hardness in macro volume allows most reasonably and accurately determine the physical and mechanical characteristics (Hh; Hd; Ae; Ap; A; P; Hhcr; Pcr; Hh/E, Hd/E) iron-nickel coatings.

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

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

Bibliography

1. **Bulychev S. I., Alekhin V. N.** *Ispytaniye materialov nepreryvnym vdavlivaniyem indentora. Moskva. Mashinostroyeniye, 224s, 1990 (in Russian).*
2. **Gologan V. F., Azhder V. V., Zhavguryanu V. N**. *Povysheniye dolgovechnosti detaley mashin iznosostoykimi pokrytiyami. Kishinev, Izd-vo Shtiintsa, 112 s, 1979 (in Russian).*
3. **Markovets M.P.** *Opredeleniye mekhanicheskikh svoystv materialov po tverdosti. Moskva , Mashinostroyeniye , 191s, 1979 (in Russian).*
4. **Javgureanu V., Ajder V., Ceban V., Pavlova S.** *The correlation of restored and unrestored microhardness of. Wear-proof iron plating. International Scientific Conference TMCR. Chisinau, pp.412-415, 2003.*
5. **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 Gala□i, Fascicle VIII, Tribology, Romania, pp.65-68, 2004.*
6. **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 Gala□i, Fascicle VIII, Tribology, Romania, pp.48-51, 2004.*
7. **Javgureanu V., Gordelenco P., Elita M.** *Le rapport de la microdurete restauree et non restauree des convertures de crome. International Scientific Conference TMCR, Chisinau, pp. 166-169, 2005.*
8. **Zhavguryanu V.N., Godelenko P.A.** *Sootnosheniye vosstanovlennoi i nevostanovlenoy mikrotverdosti khromovykh pokrytiy. Mezhdunarodnaya NTK "Mashinostroyeniye i tekhnosfera XXI veka", Sevastopol', 2005. (in Russian).*

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