International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 6 (2018) pp. 3238-3241
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Increased wear Resistance of Parts Electrochemical Alloys based on Iron

G. V. Guryanov
Professor, Department of Energy Systems, Bryansk State Agrarian University, Bryansk, Russian Federation

Yu. E. Kisel
Professor, Department of Mechanics, Bryansk State Engineering Technological University, Bryansk, Russian Federation

V. A. Bezik
Assistant Professor, Department of Energy Systems, Bryansk State Agrarian University, Bryansk, Russian Federation

D. A. Bezik
Assistant Professor, Department of Energy Systems, Bryansk State Agrarian University Bryansk, Russian Federation

O. E. Shirobokova
Assistant Professor, Department of Energy Systems, Bryansk State Agrarian University, Bryansk, Russian Federation

N. I. Yakovenko
Assistant Professor, Department of Energy Systems, Bryansk State Agrarian University, Bryansk, Russian Federation

Abstract

The influence of electrolyze modes on a microhardness, durability of coupling and wear resistance of iron-nikel coverings is studied. The structure of electrochemical coverings, providing the greatest abrasive firmless is optimized. Its shown expediency application of coverings for increase durability of details of machinery. The conditions of obtaining of composite electrochemical coatings based on iron alloys with inclusion of white alumina as a filler, which exhibit high wear resistance in conditions of abrasive wear, were found. The introduction of solid particles into alloys of electrolytic iron allows increasing their abrasive wear resistance by a factor of 8–10 in comparison with quenched steel alloys and by a factor of 4–5 in comparison with coatings without the disperse phase.

Keywords: Composite material, electrochemical coatings; resistance increase; microhardness; agricultural machinery

INTRODUCTION

The deposition of iron-based composite electrochemical coatings makes it possible to significantly expand the range of efficient application of the technology due to the considerable improvement in the quality and wear resistance of electrodeposited coatings [1–3]. The selection of an electrolyte for obtaining a composite electrochemical coating matrix and a filler is determined by the scope of the treated components and the conditions of their operation. White alumina micropowders are promising as composite electrochemical coating fillers. Meanwhile, iron-based alloys, which allow improving the physico-mechanical properties of composite electrochemical coatings, are used as a binding agent [4, 5]. However, data on their operation capability in conditions of abrasive wear are scarce. It is impossible to find the relationship between the mechanical properties of coatings and the conditions of their obtaining on the basis of the avail- able data, which limits the possibilities to select a composite electrochemical coating matrix and to objectively judge the regularities of the behavior of remanufactured components in the course of their operation. At the same time, it has not been determined in a unique fashion which sizes and volume content of particles of the disperse phase in a coating provide the highest wear resistances of composite electrochemical coatings in conditions of abrasive wear. To develop the operating procedure of the deposition of composite coatings on fast wearing components of agricultural equipment, it is necessary to study the influence of disperse phase on the operation capability of composite electrochemical coatings and to select the optimum conditions for obtaining of the most wear-resisting base.

Therefore, the aim of this work was to develop a method for the enhancement of the lifetime of fast wearing components of agricultural equipment by means of composite electrochemical coatings based on iron–nickel alloys.

The iron–nickel coatings were obtained from an electrolyte of the following composition, kg/m^3: $FeCl_2 \cdot 4H_2O$ – 500; $NiSO_4 \cdot 7H_2O$ – 100; $Na_2H4C_4O_6 \cdot 2H_2O$ – 1.5. The iron–cobalt deposits were obtained from the following electrolyte, kg/m^3: $FeCl_2$ $4H_2O$ – 500; $CoSO_4$ $7H_2O$ – 100; $Al_2(SO_4)_3$ $18H_2O$ – 80. The electrolysis modes were varied as follows: the electrolyte temperature T ranged from 30 to 80°C;

the current density *D*, from 13.4 to 46.8 A/dm^2; the solution pH, from 0.2 to 1.2. Studies of the steel preparation conditions and the determination of the possibilities to use literature recommendations concerning the anode treatment were carried out in the electrolyte, kg/m^3: H_2SO_4 – 300; $FeCl_2 \cdot 4H_2O$ – 20 [2]. The influence of the electrolysis parameters on the properties and abrasive wear resistance of the coatings was studied with the use of second-order central rotatable uniform planning at $k = 3$ [6].

The composite coating samples were obtained from an iron–nickel electrolyte suspension (ES) containing white alumina disperse phase (M2–M40 grades) in a special bath with a volume of 5 l (Fig. 1).

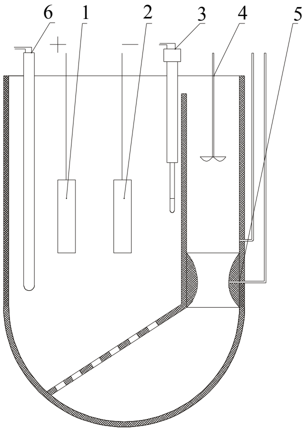


Figure 1. Bath with a concave bottom and a perforated baffle plate for deposition of composite coatings: (*1*) depicts the anode; (*2*) the cathode; (*3*) the thermometer; (*4*) the mixer; (*5*) the Venturi flow-rate meter; and (*6*) the contact heater

The velocity of the flow of the electrolyte suspension was set on the basis of the recommendations in [2]. The electrolyte suspension flow entered the working part of the bath through the perforated bottom damper. To measure the flow velocity in a separate section, a Venturitype flow-rate meter with a differential gage was designed and installed. The powder content in the ES was varied from 25 to 150 kg/m^3.

The microhardness of the coatings was determined by means of a PMT-3 microhardness gage according to the State Standard GOST 9450-76. The abrasion tests for friction using loose abrasive particles were carried out according to GOST 23.208-79 by means of an ad hoc laboratory installation (Fig. 2).

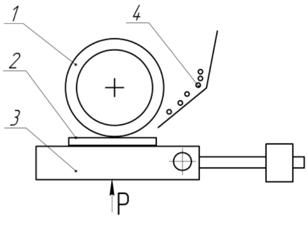


Figure 2. Diagram of the installation for the abrasion resistance testing of the samples: (*1*) is the rubber roller; (*2*) the sample;(*3*) the support; and (*4*) the abrasive material

Electrochemical coatings with a thickness of 0.5±0.1 mm were deposited on plates of steel St3 (with a length of 30 mm, a width of 30 mm, and a thickness of 1 mm). The force of the pressing of a sample to a the rubber roller *P* ranged from 20 to 88 N; the roller revolutions varied from 60 to 325 r/min, which corresponds to the variation of the relative sliding velocity V_{rel} from to 0.9 m/s. The time of the tests was governed by the necessity to obtain an appreciable value of the wear *J* (mg), which was measured by the weight method to a precision of 0.05 mg.

As an abrasive material, we used fluvial sand with a grain size of no more than 1 mm. The comparison standards were samples of quenched steel 65G, which is most commonly used for the production of cutting units of tillage equipment; “pure” iron–nickel; and iron– cobalt coatings.

RESULTS AND DISCUSSION

The studies showed that the abrasive wear resistance of the iron–nickel base in realistic conditions depends on the electrolysis parameters. By the regression analysis of factorial experiments, we obtained an empirical relation adequately describing the dependence of the wear of the electrolytic alloys on the electrolysis parameters. After the suppression of the insignificant coefficients, the equation took the following form (X_1 is the temperature, °C; X_2 is the current density, A/dm^2; and X_3 is the solution pH): $J_{Fe\text{-}Ni} = 8.8 + 0.95X_1 - 0.6X_3 + 0.69X^2_3 + 0.5X_1X_2 + +0.94X_1X_3 + 0.66X_2X_3.$

A decrease in the temperature led to an increase in the wear resistance of the coatings; the optimum value of the solution’s pH is at the center of the experiment’s design (Fig. 3). As the current density grew, the wear of the alloys increased and passed through maximum at 35–40 A/dm^2 (Fig. 3).

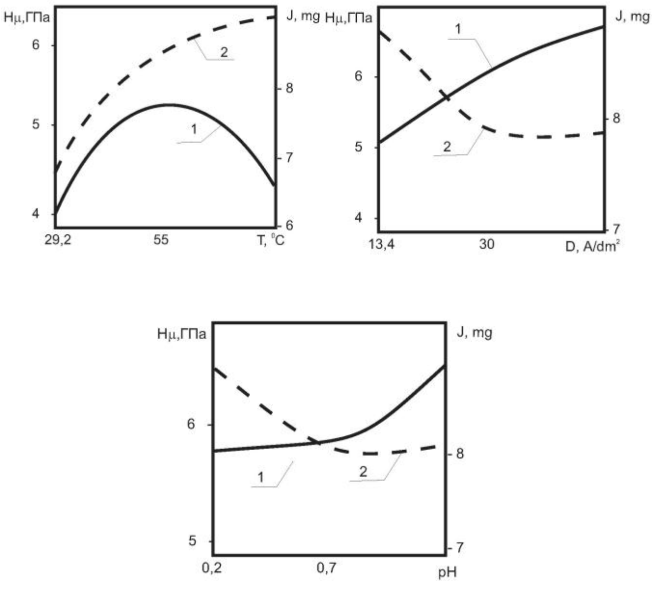
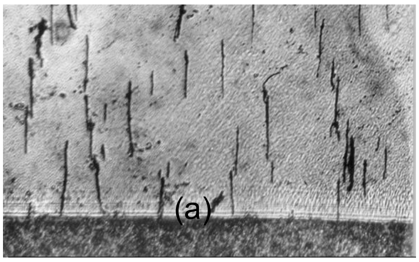


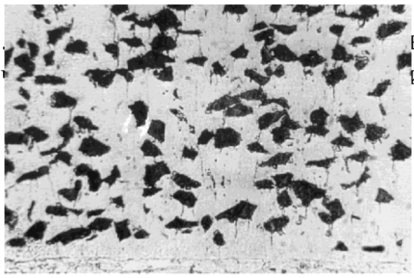
Figure 3. Influence of the electrolysis modes on the microhardness (*1*) and wear (*2*)

Thus, the optimum mode of obtaining of wear resistant deposits free from inclusions is as follows (Fig. 4,a): pH = 0.7–1.0; *D* = 35–40 A/dm^2; *T* = 40–45°C. The adherence to the recommended conditions for the deposition of the alloys allows obtaining deposits with their wear resistance being higher by a factor of 1.5–2 than that of the steel of a commercial plough [7].



a
(a)

Рис.3. вых(а) и железо-кобаль
полу имах электролиза(x500



b
(б)

Figure 4. Coating structure Fe-Ni (a) и Fe-Ni-alumina M14 (b) (×400)

The study of the influence of the content and size of the disperse phase on the wear of the coatings revealed that the solid particles of white alumina allow enhancing the wear resistance of the composite coatings under abrasive wear by a factor of 4–5 as compared to “pure” iron–nickel coatings and by a factor of 8–10 as compared to quenched steel 65G (Fig. 5). The highest wear resistance is found in the composite electrochemical coatings with the volume content of the disperse phase up to 26–28 vol. % deposited from an electrolyte suspension containing micropowder of M14 aluminum oxide in an amount of 80–90 kg/m^3 (Fig. 4,b).

(в)

Рис. 4.4. Структура КЭП на основе сплава железо-никель(x500):
а)Fe-Ni; б)Fe-N трокорунд М20.

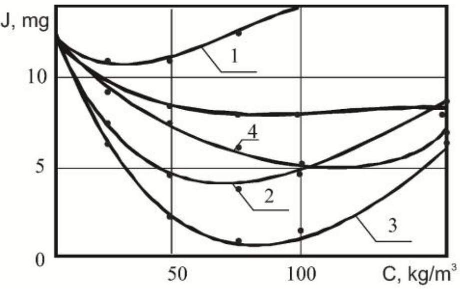
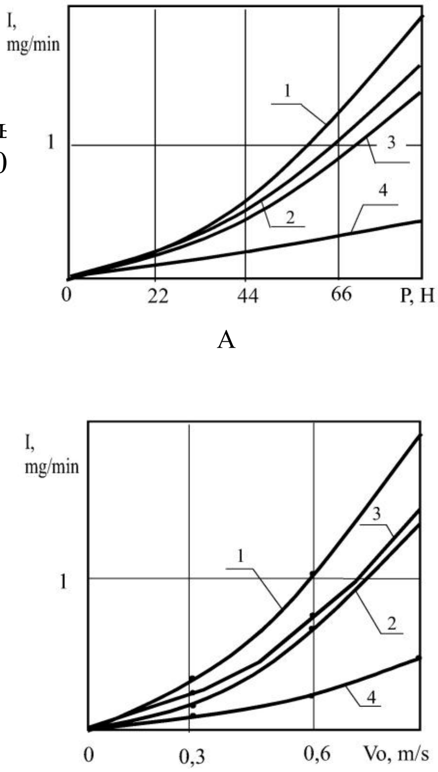


Figure 5. Influence of the particle content in the electrolyte on the wear rate of the iron–alumina deposits in contact with a loose abrasive material: (*1*) M2; (*2*) M10; (*3*) M14; (*4*) M20

In the conditions of the operation of the working parts of tillage equipment, the wear takes place most often as a result of repeated plastic deformation–redeformation of the material’s surface microvolumes by rolling abrasive grains. It is known that a variation in the sliding velocity and the force of pressing of the rubbing surfaces leads to a change in the mode of interaction between the rubbing surface and the abrasive material from the particles rolling to sliding and microcutting [8].

The analysis of the test results showed that an increase in the load and the relative sliding velocity of the friction pair led to an increase in the wear rate I (mg/min) of the standards and samples coated with the composite coatings (Fig. 6).



A

b

Figure 6. Influence of the load (a) and relative sliding velocity of the friction pair (b) on the wear rate I of the standards and the sample with a composite coating: (1) stands for quenched steel 65G; (2) iron–nickel; (3) iron–cobalt; and (4) iron–nickel–alumina M14.

In addition, the wear of the samples with iron–nickel coatings and the standard of the quenched steel 65G was more severe than that of the composite coatings. The wear rate of the composite increased lin- early with the load, remaining less by a factor of 4 than that of the coatings without the disperse phase and by a factor of 8 than the standard of the quenched steel 65G. The strongest influence on the wear resistance of the composite coatings was exerted by the relative sliding velocity; as it increased from 0.3 to 0.9 m/s, the wear varied by a factor of 1.5. At V_0 = 0.9 m/s, it was higher than the standard of the quenched steel 65G by a factor of 12.

The high wear resistance of the composite electrochemical coatings upon the stiffening of the operation conditions can be explained by the circumstance that, in the conditions of the combined wearing-out processes, the solid phase exhibits a considerable resistance to deformations and wear as well as by the fact that, with the particle inclusion, the strength of the binding material increases, although the level of its internal stresses remains relatively high. An increase in the load and the sliding velocity results in an increase in the component of the microcutting and edging of the coating surface by the abrasive particles. The filler particles play the role of contact patches and barriers at the direct destruction of the surface; they distribute the stresses and shift the process of destruction to a polydeformation one. This circumstance leads to a significant increase in the relative wear resistance of the composite coatings in comparison with coatings without disperse phase.

The field service tests of the plough shares rein- forced with composite electrochemical coatings showed that their wear resistance is higher by a factor of 1.5–2 than that of commercial plough shares [7]. The iron–nickel and iron–cobalt coatings, as well as the composite coatings on their basis, exhibited high efficiency in the reconditioning and enhancement of the wear resistance of excavator teeth, hydraulic control valve spools, friction plates, wrist pins, and lifter bodies of Diesel engines.

CONCLUSIONS

The conditions of obtaining of composite electrochemical coatings based on iron alloys with inclusion of white alumina as a filler, which exhibit high wear resistance in conditions of abrasive wear, were found. The introduction of solid particles of M14 grade in a solution of 80–90 kg/m^3 (in a coating of 26–28 vol. %) into alloys of electrolytic iron allows increasing their abrasive wear resistance by a factor of 8–10 in comparison with quenched steel alloys and by a factor of 4–5 in comparison with coatings without disperse phase.

REFERENCES

[1] N. Tsyntsarua, H. Cesiulisc, M. Dontend, J. Sorte, E. Pellicerf, and E. J. Podlaha-Murphyg, 2012, Modern Trends in Tungsten Alloys Electrodeposition with Iron Group Metals, Surface Engineering and Applied Electrochemistry, 2012, Vol. 48, No. 6 (in USA)

[2] E.A. Vasil'eva, I.V. Smenova, V.S. Protsenko, T.E. Konstantinova, F.I. Danilov, 2013, Electrodeposition of Hard Iron–Zirconia Dioxide Composite Coatings rom a Methanesulfonate Electrolyte, published in Zhurnal Prikladnoi Khimii, 2013, Vol. 86, No. 11, (in USA)

[3] Gobinda Gyawali, Sung Hun Cho, Soo Wohn Lee, 2013, Electrodeposition and Characterization of Ni-TiB_2 Composite Coatings, Met. Mater. Int., 2013, Vol. 19, No. 1 (in Korea)

[4] Guryanov, G. V., and Kisel, Yu. E., 2015, Wear-resistant Electrochemical Alloys and Composites on Iron Based, Bryansk, BGITA Publ. (in Russian)

[5] Yu.E. Kisel, G.V. Guryanov, D.M. Kroitoru, 2009, Wear Resistance of Composite Electrochemical Coatings Based on Iron Alloys, Surface Engineering and Applied Electrochemistry, Vol. 45, No. 6 (in USA)

[6] Yu. E. Kisel, I. N. Serpik, G. V. Guryanov, 2015, Calculation of the Elastic Characteristics of Composite Materials with Dispersed Inclusions, International Journal of Applied Engineering Research. Vol.10, No.24 (in India)

[7] Tenenbaum, M.M., 1976, Soprotivlenie abrazivnomu iznashivaniyu, Moscow, Mashinostroenie, (in Russian)

[8]. Yu. E. Kisel, G. V. Guryanov, 2017, Wear Resistance of Electrochemical Alloys Based on Iron. Selskiy Mechanizator, 2017. No. 2 (in Russian)

[9] Kisel, Yu.E., 2014, Enhancement of Lifetime of Fast Wearing Components of Agricultural Equipment by Composite Electrochemical Coatings Based on Iron Alloys, Extended Abstract of Cand. Sci. (Eng.) Dissertation, Moscow, (in Russian)