Restoring of worn-out parts of electrical machines via compositional electrochemical iron-corundum coating

V I Panteleev, R A Petukhov and E Yu Sizganova
Department of electrotechnical complexes and systems, Siberian Federal University, Krasnoyarsk, 70 Lenin st., 660049, Russia
E-mail: rompet1@mail.ru

Abstract. Galvanic build-up of iron layer is an effective method of parts restoring during repair works. The productivity of this process is 15-20 times higher than of chroming. The high settling velocity of iron and low costs of the source material determine the economic practicability of this method. Up to 3 mm can be applied by iron plating, which is necessary in case of high parts wear.

1. Introduction
Nowadays friction members of electrical machines (bearing seats, spindles) are subject to higher standards of wear-resistance of coatings that can sustain prolonged high mechanical and thermal loads as well as successfully withstand the negative effects of deterioration, corrosive media, cyclic and contact stresses. The new method of acquiring these coatings implements a well-known principle borrowed from nature. The main point of this principle is that the joint action of dissimilar materials gives an effect equal to creating a new material the properties of which are different from the properties of each of its components.

Electrochemical iron coatings for restoring the geometrical properties of worn machine components are characterized by the appearance of micro-fractures with increasing of coating thickness, which leads to the microhardness and wear-resistance not being high enough.

More qualitative coatings allow the addition of corundum dust to the electrolyte (aluminum oxide Aℓ₂O₃). The solid oxide particles (corundum microhardness is 22-25 hPa) increase the wear-resistance of electrochemical iron coatings during the work of mating parts in lubricant as well as in dry friction, which significantly reduces the tearing of rubbing surfaces [1,2].

The use of composite electrochemical surfaces iron-corundum reduces the amount of cracks in the coating. The positive effect of corundum particles is especially noticeable in the formation of brittle coatings (low temperatures and high current densities). The nature of this phenomenon can be explained by the fact that the realization of internal tensile stresses which are characteristic of electrolytic iron occurs around the particles of the second phase of coating.

Compared with the coatings based on the pure electrolytic iron and the iron with titanium carbide additives, iron-based composite electrochemical coatings with corundum additives have high wear-resistance and at the same time are not sensitive to shock loads, i.e. non-brittle. This kind of coating can be acquired by combining a ductile metallic matrix and hard oxide particles, which can show signs of plasticity under conditions of comprehensive compression. With an increase in the concentration of
oxide particles in the coating, its wear resistance increases, which reaches its maximum with a sufficient amount of these particles to absorb the load, and the volume of the metal matrix (ligament) is still so large that it is able to keep the particles from spalling. A further increase in the concentration of solid oxide particles in the coating leads to a decrease in the volume of the metal binder. Subsequently, the amount of solid particles in the coating becomes so vast that they begin to touch, minimizing the effect of the matrix on the strength of the composition. This leads to spalling of the coating particles even under insignificant loads, that is, the chemical bond with the matrix is broken, and only the mechanical one remains. As the spall, particles in large quantities fall into the friction zone, dramatically increasing the wear of the coating.

The process of iron plating is carried out in chlorine, sulfate, and mixed electrolytes. The most commonly used chloride electrolytes are the ones characterized by a high concentration of salts, the intensity of sediment build-up and the possibility of obtaining coatings of greater thickness. The composition of the electrolyte is ferriferrous chloride FeCℓ2 700 g/l, alumina oxide (corundum M5) Aℓ2O3 50-75 g/l. It is necessary to maintain the anodic and cathodic current density of 20-25 A/dm2 and the electrolyte temperature not lower than 40 °C [2].

When mating parts work with electrolytic iron coatings in a lubricant contaminated with abrasive particles, solid oxide particles increase the wear-resistance of coatings.

Analysis of the influence of aluminum oxide concentration Aℓ2O3 on the wear rate of the coating and the main cast-iron part when working in oil showed that the iron-corundum coatings obtained from an electrolyte with an additive concentration of 50-100 g/l, with a specific pressure of 1.5 MPa, have 6.5 - 7.5 times more wear resistance than pure electrolytic iron. The wear of the cast iron box with such a coating decreases from 2.8 to 1.9 mg/h (figure 1).

![Figure 1](image.png)

**Figure 1.** The effect of the concentration of aluminum oxide Aℓ2O3 on the rate of wear:
1 – wear of coating, 2 – cast iron detail wear.

To assess the effect of the specific pressure on the wear rate of composite electrochemical coatings based on iron, experiments were carried out at specific pressures: 25; 50; 75 MPa, which showed that coatings obtained from electrolytes with aluminum oxide concentration Aℓ2O3 have the optimal wear resistance under such friction conditions [3].
The effect of specific pressure on the rate of wear
1 - 40X steel, 2 - pure electrolytic iron, 3 - iron molybdenum disulfide 6 g/l, 4 - iron-titanium carbide 50 g/l, 5 - iron-corundum 50-75 g/l.

The study of wear of coatings with dry friction showed great advantages of composite electrochemical coatings with aluminum oxide over other types of coatings and pure electrolytic iron (figure 3). So, with a specific pressure of 8.1 MPa, the rate of wear of pure electrolytic iron was 91 mg/h, precipitation of iron-boron carbide — 29.4, and precipitation of iron-alumina oxide (50-75 g/l) 5 mg/h[3,4,5].

Galling and catastrophic wear of soft (microhardness of 4.5 GPa) coatings of iron-titanium carbide began already in the first minutes of work at 4.0 MPa (figure 3, curve 1). The first signs of solid electrolytic iron setting (microhardness of 5.8 GPa), consisting in the oscillation of the friction moment, occurred at 5.5 MPa (figure 3, curve 3). Wear at the axle increased sharply. Perhaps due to the abrasive effect of the dispersed particles of iron, the wear of the coating also increased. But the brown deposit of oxides present on the surface of the coating helped to prevent the intensive galling and tearing of surfaces [5,6].

Studies on the wear of electrolytic iron coated parts and composite iron-based electrochemical coatings for 20 minutes with dry friction with a conjugated cast iron coat showed the following:

- Scratches already appeared on the surface of the electrolytic iron coating at a specific pressure of 15 MPa, which led to a significant chipping of the upper coating layer and, as a consequence, increased wear;
- On the surface of the iron-corundum coating, even at a specific pressure of 25 MPa, no galling or local damage to the upper layer was formed.

The wear rate of composite electrochemical coatings based on iron with dry friction: 1 - iron-titanium carbide 50 g/l, 2 - iron-molybdenum disulfide 6 g/l, 3 - pure electrolytic iron, 4 - boron iron-carbide 100 g/l, 5 - iron-corundum 50-75 g/l.
2. Conclusion
A promising direction for the development of a new electrotechnical complex for the restoration and strengthening of worn-out machine parts, applying composite electrochemical coatings (CEP), using different forms of periodic current has been determined.

Studies of the wear-resistance of composite electrochemical coatings based on iron, obtained from chloride electrolyte with the addition of corundum powder, showed wear to the coating decreases by more than 4-5 times, and the coefficient of friction from 0.1 to 0.02. Such coatings are recommended for industrial use in order to restore and harden parts of electrical machines.

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