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**«Science & Research
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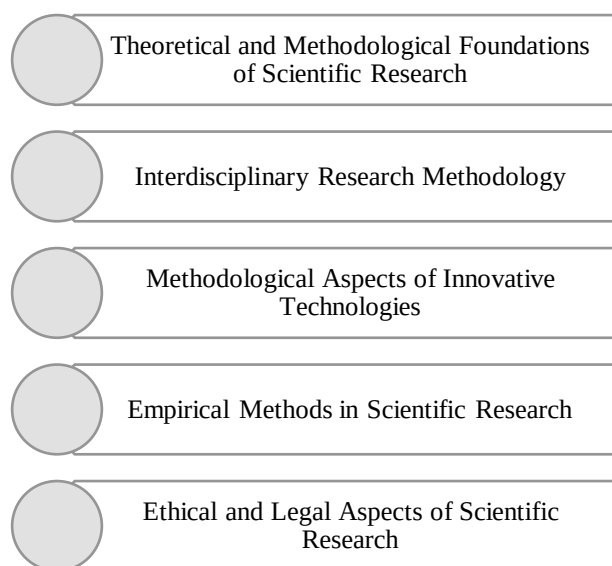


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WEAR CONTROL OF HIGH-PRECISION SLIDING ELECTRICAL CONTACTS IN LOW-SPEED APPLICATIONS

Abstract. The article discusses approaches to increasing the durability and stability of electrical parameters of precision low-speed sliding contacts. The purpose of the work is to reduce wear and transient resistance while providing the required friction moment by optimizing coatings and the technology of their formation. The use of electrochemical gilding with alloying and nickel sublayer, as well as the procedure for running-in of the surface, is proposed; a test scheme is given (brush-ring bench, friction machine SRV) and evaluation criteria. It is shown that the correct selection of the composition and thickness of the coating layers, as well as treatment after application, can reduce the intensity of wear and stabilize contact resistance in operating modes. The results can be applied in current collectors of gyroscopic and other mechano-electrical devices.

Key words: coating, electrochemical gilding, transient resistance, coefficient of friction, current collector.

Introduction. Sliding contacts provide reliable electrical communication in nodes where there is a relative movement of friction pairs (for example, "brush - ring"). Mechanical, thermal and electrical loads simultaneously act on them, which leads to degradation of surface layers, an increase in transient resistance and a decrease in the accuracy of the system.

World studies in recent years demonstrate the effectiveness of coating engineering and multilayer systems for sliding contacts: nickel sublayers, solid gold and composite layers with carbon components reduce wear and stabilize contact resistance; Test benches for brush-ring modeling and analysis of triboelectric behavior, including fretting-wear, are actively developing [1-5].

The article is aimed at substantiating and experimentally supporting technological solutions for the formation of wear-resistant coatings of sliding contacts (gold with alloying and/or nickel sublayer) and indicating how the selection of the structure of layers and running-in modes affects wear, friction moment and transient resistance in typical bench tests.

The object of research is the details of friction contacts of precision mechano-electrical devices; The subject is the formation of the coating structure and its effect on the wear resistance and current conductivity of working surfaces. The approach is based on the "composition – structure – properties" relationship and combines electrochemical layering with subsequent running-in, micromechanical tests and AFM control.

For low-speed contacts, it is advisable to use gold due to its high electrical conductivity and corrosion resistance; the nickel sublayer increases adhesion and wear resistance, and silver alloying or the formation of thin silver-carbon structures helps to stabilize resistance under load. Electrochemical gilding with adjustable thickness and alloying is proposed as an application technology: pure Au; Au-Ag (silver alloying in a bath); Ni/Au (hard nickel sublayer followed by gilding); Ni/Au-Ag. For individual options, the operating concentrations of the electrolyte components and the duration of the process are given; After application, running-in is used to form a stable contact layer, Table. 1.

Table 1. Coating options and their expected properties (qualitative assessment)

Coating option	Adhesion	Durability	Resistance stability	Complexity of technology	Note
Au (clean)	Average	Average	High	Average	Basic option
Au-Ag (alloying)	Average	Increased	High	Average	Improved conductivity
Ni/Au	High	Increased	High	Higher	better mechanical layer support
Ni/Au-Ag	High	High	High	Higher	Wear/Resistance Trade-Off

Friction processes are simulated on the SRV machine and on a special stand with geometry "4 brushes from PLI-25 - brass ring", which reproduces the "brush - ring" assembly, Table 2. Basic metrics: wear rate (mass flow rate or height reduction), friction coefficient, transient resistance/voltage drop, stability of parameters over time.

Table 2. Example of test modes

Stand	Load	Linear speed	Amperage / voltage	Duration	Main outputs
SRV Machine	10-50 N	0.05–0.5 m/s	up to 5 A / up to 24 V	30–120 min	coefficient of friction, mass loss
"Brush - ring"	5–20 N (per brush)	0.1-1 m/s	up to 10 A / up to 48 V	Year 10–50	transient resistance, parameter stability

The state of the surface before and after tests is monitored by atomic force microscopy (AFM). Thus, the formation of layers with a changed composition, in particular, silver-carbon structures up to hundreds of nanometers thick, which affect friction and conductivity, has been recorded.

According to the literature [3], solid gold on the nickel sublayer and other engineering solutions (including composite carbon-containing layers) reduce wear intensity and stabilize contact resistance in a slow-sliding mode consistent with the objectives [3].

Conclusions. The use of multilayer coatings (Au, Au-Ag on the Ni sublayer) for low-speed sliding contacts in order to reduce wear, stabilize transient resistance and ensure friction torque is substantiated. Technological options for electrolyte composition and post-processing, as well as a test scheme (SRV, "brush-ring") and evaluation criteria are given, which creates a practical basis for implementation in current collectors and adjacent units. Combination of nickel sublayer, solid gold and/or carbon-containing modifications provides a better compromise between wear resistance and electrical conductivity in precision units.

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