Formation of film antifriction coatings on the friction surfaces of machine parts

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Abstract. The article presents a study of the adhesion strength of film anti-friction coatings. The process of a film anti-friction coating formation is described. An experiment to determine the adhesion strength of a film anti-friction coating is considered. In the course of the experiment, a number of samples of different roughness were used on which an anti-friction coating was applied. The thickness of the coating was controlled by a thickness gauge. Conducted a qualitative assessment of the adhesive strength of the coating with the base metal. Conclusions about the strength of adhesion, its dependence on surface roughness and initial surface treatment are made.

1. Introduction
Reliability and durability of machine parts and mechanisms is determined by the constructive strength of the materials from which they are made. The performance characteristics of many products — wear resistance, corrosion resistance, reflectivity, thermal resistance, and others — are determined by surface properties. To obtain high constructive strength characteristics of surface layers, various coating methods are often used to protect the base material from external influences, increase the service life of parts and reduce the cost of repairing worn equipment. Coatings are artificially created surface layers that may differ from the base material in chemical and phase compositions, structure and properties. Coatings are applied to protect the surface from various types of impacts (high loads, temperatures, various corrosive environments), for decorative purposes, and to restore the broken geometry of products [1, 2]. Improving the performance of machine parts is closely connected with the use of new materials film coatings and technological processes of their application. The use of new technological processes of application, especially in the initial operations, will significantly improve the performance characteristics of the working surfaces of machine parts.

2. Problem formulation
Modern technologies allow the creation of various thin-film coatings to improve the tribological characteristics of friction pairs. One of the most modern and promising ways to protect various mechanisms from intense wear is the use of thin film anti-friction coatings. [3]. In the composition of the film anti-friction coating, molybdenum disulfide, graphite and PTFE, as well as nanoparticles are mainly used as pigments. Selection of an optimized amount and composition of composites, which consist of polymers and widely used fillers, is one of the key tasks, the solution of which can increase the possibility of using film anti-friction coatings in industry [4, 5]. The study of the tribological...
properties of film anti-friction coatings plays one of the main tasks in their formation. [6, 7]. The study of the thickness of the antifriction layer of film coatings, its strength of adhesion to the base, and the preparation of the surface for its application deserve special attention in order to provide further recommendations for their wide application.

3. Theoretical part
The process of a film anti-friction coating formation can be represented as three successive transitions:
- surface pretreatment (roughness creation and decontamination) in order to increase the adhesion strength of the applied coating to the base (metal, plastic, etc.)
- applying the first intermediate layer in order to level the surface;
- build-up of anti-friction coating (application of one or several layers).

The presented process has much in common with the application of a paint and varnish coating. It is known that the adhesion and the service life of the paint coating depend on the method of preparing the surface of the part, and on the value of its roughness. To assess the adhesion, thickness and microgeometry of the surface of the film antifriction coating, we will use techniques applicable to the paint coating [8, 9].

4. Experimental studies
For comparative tests, nine samples were prepared, which were rectangular plates (flat, not deformed) with a length of 150 mm, a width of 100 mm, and a thickness of 3 mm. All samples were subjected to pretreatment (surface polishing, surface grinding, sandblasting) to create various roughness parameters on the surface (figure 1).

![Figure 1. Samples for research.](image)

The roughness parameters of each sample were measured using a model 171621 profilometer at six locations (figure 2).

The arithmetic average value for the roughness parameter Ra for samples: after polishing the surface was 0.75 \( \mu \)m, after sand blasting 1.1 \( \mu \)m, after grinding the surface 1.75 \( \mu \)m.

Before applying the antifriction coating, the samples were treated with an organic solvent to remove contaminants.
Figure 2. Roughness measurement:
a) scheme of measurements; b) roughness measurement process

Anti-friction coating (PTFE-based coating with an acrylic binder, curable at normal temperature) was applied by spraying (figure 3).

Figure 3. Samples coated with anti-friction coating.

Two layers of coating were applied, with each subsequent layer applied after the previous one was completely dry. The thickness of the anti-friction coating layer was controlled after each applied layer using a thickness gauge ET 11P (figure 4). The measurements were performed on the expected test sites, while the magnitude of the measurements did not exceed 7%, which meets the requirements.
After the coating was applied, the roughness parameters of each sample were measured again on a model 171621 profilometer in order to have an idea of the effect of the applied coating on the surface microgeometry. The arithmetic average value obtained for the roughness parameter Ra for samples: after polishing with coating application 0.44 \( \mu \text{m} \), after sandblasting with coating application 0.81 \( \mu \text{m} \), after grinding the surface 1.5 \( \mu \text{m} \).

To conduct a qualitative assessment of the adhesion strength of the coating, using special cutting tools prepared by stencils (blade width 0.43 ± 0.03 mm, with a cutting angle of 200°), grid cuts were made (rectangular grid) on the prepared samples. Herewith, all the cuts cut through the applied anti-friction layer. After that, the plate was cleaned with a soft brush, along both diagonals of the lattice. To check the adhesion between the steel plate and the anti-friction layer, adhesive tape was used. To exclude the possible drying of the adhesive layer, before starting the tests, two full turns of adhesive tape were removed from the coil.

Cutting off a piece of tape of the required length, put it on the grating parallel to one of the directions of the notches, then smooth the tape with finger, press it to the surface of the grid notch. The color of the coating visible through the tapem, is an indication of complete contact. 5 minutes after applying the tape, we remove it, taking it by the free end and tearing it off smoothly in one second at an angle of separation close to 60° (figure 5). A special device was used to control the tear-off effort of the adhesive tape.

**Figure 4.** Measurement of the thickness of the antifriction layer using a thickness gauge ET 11P:
- a) first layer measurement parameters;
- b) second layer measurement parameters

**Figure 5.** Removing of adhesive tape.
The sample obtained (figure 6) has undergone a qualitative assessment of the adhesion strength of the coating to the base metal. The appearance of the cuts surface of the test coating was examined, in good light, from different sides and from different angles using a magnifying glass tenfold magnification.

Figure 6. Plate after removing adhesive tape.

As a result of processing the experimental data, the results presented in figure 7.

Figure 7. The influence of surface preparation methods on adhesion strength.

5. Conclusions
As a result of the research, it was found that the application of a film anti-friction coating affects the surface microgeometry, significantly reducing the roughness parameters on the surface of the samples, thereby reducing the friction coefficient.

The experimentally detected indications of the adhesion strength of the film anti-friction coating (expressed in % of the coating detachment from the total area of the cuts), depending on the method of
surface preparation, satisfy the theoretical assumptions. Thus, the results obtained make it possible to
draw the following conclusions that the method of surface preparation affects the adhesion strength,
and the magnitude of this effect is insignificant. Evaluation of the quality of the coating showed that
the adhesion of the coating did not exceed the permissible norm on all the samples studied. According
to the requirements for coatings, the percentage of coating detachment from the total area of the lattice
notch should not exceed 15%. In our case, the maximum percentage of coating delamination was
11%. In this case, the separation of the coating between the layers was not noticed.

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