Increasing the operating life of parts of weaving equipment

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Abstract. The work is devoted to increasing the operating life of parts of weaving equipment. The method of accelerated wear tests is considered. Technological approaches for applying a wear-resistant coating to parts of weaving equipment are identified. Coatings from powder materials PG-10N-01 are promising for hardening the friction surfaces of parts of weaving equipment. The operating life of parts with coatings according to the wear resistance criterion is increased up to 15 times concerning the parts with coatings made of TSP-6. Under existing operating conditions, emergency situations due to delamination of the coating are excluded.

1. Introduction
Polymers and their compositions are increasingly used in various industries in structural elements, as well as in sliding / rolling pairs of components such as bearings, rollers, camming means, etc., where their self-lubricating features are used to avoid the need for oil or grease with all the ensuing pollution problems [1]. However, when there is contact between the sliding pairs, the problem of friction and wear arises [2], as well as the choice of materials in the friction pair, which leads to the decrease of the friction coefficient [3], and wear resistance can be reduced by choosing the right material combinations [4].

The use of polymer composite materials in the friction and contact interaction with solid moving materials shows that the hardness of the friction surface of the polymer material must be increased [5]. The main ways to increase the wear resistance, for example, glass-filled polyamide PA 6, with mechanical wear are improving the quality of the surfaces, increasing the hardness of the friction surfaces, selecting materials of friction pairs, reducing contact pressure on the friction surfaces [6]. In the study of friction and wear resistance of a fiberglass reinforced polystyrene composite, the results of which showed that in general, all test parameters, such as applied load, sliding speed, sliding distance and fiber orientation, have a strong influence on friction and wear [7]. In addition, it was found that the applied normal load, sliding speed and fiber orientation have a big effect on the wear rate [8], it is noted that the sliding speed has a more significant effect on sliding wear compared to the applied load, and variations in the wear rate with working time can be allocated for three different periods. These periods are the running-in period, the steady-state period and the period of intense wear, it is shown that reinforcing with fiber or filler significantly improves the tribological properties of the polymer material [9]. It is not always justified to apply wear-resistant coatings to the friction surface of composite materials to reduce the coefficient of friction and wear [10].

The widespread use of aluminum alloys in friction units of weaving equipment gives a great positive effect, and also allows to improve the tribological parameters and operational characteristics of machines and assemblies by reducing their mass and dynamic loads. Aluminum alloys can be subjected to
hardening heat treatment, and a wear-resistant coating can be applied on the friction surface [11, 12]. Technological modes of deposition of wear-resistant coatings were considered in [13], where the influence of processing time, current density, current frequency of plasma electrolytic oxidation on the microstructural, mechanical, and sliding wear of the surface of ceramic coatings is studied. The main wear mechanisms controlling soft and hard modes are associated with brittle crack propagation [14]. To increase the adhesion strength of the coating, laser fusion is applied to the base [15]. A search is under way for increasing the resource of machine-building parts using wear-resistant coatings [16, 17]. The high efficiency of plasma gas thermal technology, which increases the resource by 4 or more times and improves the technical characteristics of engine parts, allows to save money and material resources significantly [18]. The quality of the sprayed plasma surfaces is determined by the preparation of the surface for sputtering, that is cleaning and degreasing surfaces. Improving the wear resistance of parts of weaving equipment made of aluminum alloys, working in a pair of friction with fiberglass, is one of the tasks of increasing the service life of nodes and assemblies.

The purpose of this work is to increase the operating life of weaving equipment parts by increasing the wear resistance of the friction surfaces of aluminum parts using gas-thermal coatings.

To achieve the goal, the research was conducted in the following areas:

- the choice of wear-resistant coating to increase the operating life of parts of weaving equipment;
- to develop a technology for applying a wear-resistant coating;
- to examine the wear resistance of the applied coating.

2. Materials and equipment

The work considers the details of weaving equipment - winding rollers Ø26x290 mm, made of aluminum alloy D16 and coated with glass-filled polyamide TSP-6. The rollers track the direction of movement of the yarn folding mechanism while increasing the volume of winding on the reel. The rollers are constantly in contact with the rotating reel. The frequency of own revolutions is from 10 to 12 thousand rpm, while the load is 10 ... 20 N per roller. TSP-6 is coated on the rollers; its wear resistance under the existing operating mode is insufficient [19]. To increase the wear resistance of the rollers instead of the TSP-6 coating, it was decided to apply a gas-thermal wear-resistant coating. The coating process was carried out on a UPU-3D plasma installation, while a plasmatron developed at A.A. Blagonravov Institute of Mechanical Engineering RAS with a power of up to 40 kW was used. The plasmatron provides a plasma flow rate of 0.7-0.8 M, with an enthalpy of 1.3 x 10^7 J/kg. Coefficient of efficiency is at least 0.7. An important feature of the gas-dispersed flow is the opening angle of the flow, which is no more than 3 ... 5 °. The spraying performance of the powder material was 5 ... 7.5 kg/h. Coating the rotation parts of weaving equipment is shown in figure 1.

![Figure 1. Plasma application process coatings on parts of weaving equipment.](image-url)
The part rotation mechanism is set on the technological table, which moves relative to the plasma jet. Technological equipment provides a uniform thickness of the applied thermal coating.

3. **Theoretical part**

When plasma coating of wear-resistant coatings, it is necessary to comply with the requirements for the choice of particle size distribution of powder materials. The granulometric composition is determined with the possibility of providing heating and subsequent melting of the particles. For specific plasma parameters, the particle size distribution of the powder material is theoretically calculated, for example, for argon-nitrogen plasma with an enthalpy \( i = 10^7 \) \( j/\text{kg} \), the particle diameters of the powder material should be in the range of 20 ... 63 microns. The lower limit of the particle size distribution of the powder is determined from the calculation of the heating of the powder near the obstacle, as well as from the solution of a system of equations describing the process of injection of the powder material into the plasma and its heating. To ensure uninterrupted and constant delivery of powder material into the plasma jet, it must have good flowability, otherwise it cannot be constantly heated. Fine fractions (lower range \( \sim 20 \) microns) and powder materials with a small specific gravity (less than 4000 kg / m\(^3\)) should have a particle shape close to spherical. The industry currently produces a wide range of powder materials suitable for wear-resistant coatings. Wear-resistant coatings made of powder materials of the intermetallic class are widely used: PT65U35, PN70U30, PN55T45, PN88T12, PN85U15 and others, as well as self-fluxing PG-10-N-01 (composition, %: C-0.6 ... 1.0; V -2.8 ... 3.4; Si-4 ... 4.5; Cr-14 ... 20; Fe-34; Ni - base), etc. To increase the wear resistance of the friction surface, it is necessary to take into account many design and operational parameters, for example, surface roughness and hardness, friction pair load, sliding speed, lubrication conditions, temperature, etc. To accelerate the development of technological application of wear-resistant coating and the choice of powder material to increase the wear resistance of aluminum parts from a very wide range of powder materials for thermal spraying, it is necessary to have an express method for analyzing the wear resistance of plasma coatings. The express method, taking into account certain assumptions, should rank the applied technological regimes and the used powder materials by the level of wear resistance. Otherwise, if we simulate the full-scale working conditions of real friction pairs, taking into account the rather long duration of wear tests, the choice of the most suitable powder materials and the technological modes of their application is a technically difficult, time-consuming and expensive task. The use of accelerated wear test methods for coating friction testing laboratory machines is a promising task. Friction machines, the tested samples of which form a higher kinematic pair, were widely used for accelerated wear resistance tests [20]. The test setup for abrasive wear is shown in figure 2.

![Figure 2](image)
In comparative wear tests, one of the samples of claim 2 is a reference abrasive body, and the other of claim 1 is made of the test material. At the initial moment of testing, the contact area of the samples is calculated by the formulas of the theory of elasticity. At the initial moment, due to the small size of the contact surface, the average contact pressure is relatively high, which determines the rapid formation of a wear hole, the size of which judges the wear resistance of the material. Of the existing accelerated test methods, a test method in which a flat sample is abraded by a reference disk is of interest. Abrasive material is fed into the friction zone [21]. The abrasive disc is made of rubber in order to exclude the influence of the counterbody material on the results of comparative tests. With increasing test time, the friction surface gradually increases, the number of abrasive particles that are simultaneously on the friction surface and absorb the load increases. Test results can only be compared under identical conditions.

4. Results of the experiment
The wear resistance of the applied coatings was determined by the method of accelerated tests on a laboratory Brinell-Hawort type friction machine. The samples are made of aluminum alloy D16, had a rectangular shape of 90x20x10 mm. The samples were coated with a plasma wear-resistant coating of powder materials: PN70Y30, PN80X20, PG-10N-01. Testing of samples with coatings occurred during friction against a rubber disk, the contact pressure between which was 1 MPa. The abrasive, in the form of quartz sand, previously dried in a furnace, was fed into the friction zone. The line rate of the rubber disc in the area of contact with the test sample was 2.5 m/s. The test time was 30 minutes. According to the test results, the weight wear of the $\Delta G$ samples was measured on a Shinko Vibra HTR-220 CE analytical electronic balance, that is the difference in weight of the samples before and after the tests.

![Figure 3. The coefficient of wear resistance of materials and coatings: 1-TSP-6, 2-D16, 3-SCh18-36, 4-PN70Yu30, 5-PN80X20, 6-PG-10N-01.](image)

Weight wear was recalculated for volumetric wear $\Delta V=\Delta G/\rho$, where $\rho$ is the specific gravity of the material or coating. The determination of volumetric wear is important because the main indicator of wear of full-scale parts of weaving equipment is wear of linear dimensions. To determine the effectiveness of surface hardening of the sample, a coefficient $K=\Delta V_s/\Delta V$ is introduced, where $\Delta V_s$ is the volumetric wear of the standard sample, $\Delta V$ is the volumetric wear of the test sample. As a standard, the wear of a standard glass-filled polyamide TSP-6 was determined on a Brinell-Haworth type testing machine. The weight wear of the sample coated with TSP-6 was 0.4452 g, and the volume wear was 0.1 cm$^3$. For comparison, the coefficient of wear resistance in relation to TSP-6 shows materials aluminum alloy D16 and cast iron SCh18-36. The results of comparative tests of materials and
coatings are shown in figure 3. The applied wear-resistant coatings from materials PN70YU30, PN80H20, PG-10N-01 provide an increase in wear resistance by 9-15 times relative to TSP-6. The most wear-resistant is a coating of PG-10N-01 material.

5. Conclusion
Coatings from powder materials PG-10N-01 are potential for hardening the friction surfaces of parts of weaving equipment. The operating life of parts with coatings according to the wear resistance criterion is increased up to 15 times relative to parts with coatings made of TSP-6. Under existing operating conditions, emergency situations due to delamination of the coating are excluded.

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