The possibility of modifying the elements of the bearing assembly with nanoparticles in order to reduce the friction coefficient

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Abstract. Recent study considers the tribological characteristics of the sintered bushings used in the connecting nodes brake lever system of railway cars. Particular attention is paid sleeves low content of alloying elements. Bushings had been prepared by powder metallurgy route by using low alloyed powders of Fe-Cu-C system. Porosity after sintering was about 20%.

Generally, before using material was impregnated by industrial mineral oil in order to improve friction condition.

In the recent study we use new lubricating compositions for impregnating in sintered bodies. Such compositions consist of basic mineral oil with addition of 4 wt.% of layered tungsten dichalcogenides (WS₂ and WSe₂) nanoparticles, which were ultrasonically dispersed. Tungsten disulphide nanoparticles have spherical shape with the diameter of 30-50 nm, and diselenide nanoparticles have a flat shape with the mean dimensions of 5x70 nm. Tribological testing of the product was provided. Sintered bushings impregnated with commercial oil and suspension of nanoparticles were tested in the spinning friction conditions in the couple with bearing steel at the load of 210 N and spinning rate of 200 rpm.

The friction test in couple with steel exhibited the value of friction moment to be about 2 times less as compared with commercial oil. The additions of tungsten disulphide nanoparticles also significantly decrease oscillations the friction torque.

1. Introduction

The powder metallurgy is still the common way for production of sintered bushing for most of machines and mechanisms. Main advantage of this technology is practically total absence of waste products and controllable porosity in produced materials. [1] Friction, wear and lubricant play significant role in economical effect by the determining of the lifetime of machines and mechanisms. [2] Side effects of friction and wearing, changing the geometry and vibrations during the exploitation brings to the loosing functionality by the dramatically breakdown or progressive failure of friction parts. It’s important to consider for production of parts for railway and automotive industry.

Factors influent significantly on wearing and friction coefficient depends not only from properties of initial materials, but also from number of parameters. Even insignificant changes in contact area of surfaces, temperature and humidity in contacting zone brings to the significant changes in wear rate and
friction coefficient value of powder metallurgy parts. Also the main important factors are sliding velocity, viscosity of grease and normal force action in lubricating systems. [3]

Tendency to the ecological and economical efficiency in development of new tribological materials and systems is strength during the last ten years. In this area were investigated oxide- and nonoxide modified ceramics, metal-glass materials and materials modified by nanodispersed particles.

Nanoparticles application allows improving chemical resistance and tensile strength in low- and high temperature conditions. In this way the big interest is to the possibility to decrease friction coefficient and wear of powder bushings.

Among the modifying additives are carbides, borides, metal oxides. The greatest application was found for carbon materials (carbon nanotubes, fullerenes and ultradispersed diamond-graphite compositions). In the work [4] the method of increasing tribological properties by using bearing lubricants activated with nanoscale diamond-graphite additives is considered. For practical use, the treatment of a material in electrolytes by prolonged immersion is most often used. This ensures a reduction in roughness, an increase in the stability of the rheological properties of the liquid lubricant materials.

The results of studies of the use of solid lubricants based on metallic dichalcogenide compounds, such as an additions of molybdenum and tungsten disulphides are presented in [5]. It is noted that tungsten disulfide is more stable at temperatures above 300 ° C. The synthesis of WS2 particles was considered in detail in [6].

Based on those researches we have studied a possibility to decrease a friction coefficient of sliding bearing assembly by using nanoparticles of tungsten disulfide and diselenide in lubricating oil.

2. Materials and methods

Studies were carried out by using of bushing of brake lever system made of Fe-Cu-C material [7]. Microstructure and general appearance are shown in the Fig.1.

![Figure 1. Microstructure -a, and photographs of bushings –b.](image)

The bushings from this alloy were manufactured by powder metallurgy route. A multicomponent powder mixture ANS100.29 + Cu + Ni + C was used for the manufacture of MKV. An estimation of roughness parameters of metal-powder products was considered in [8]. The physical and mechanical properties and dimensions of the test material are shown in Table 1.

| Parameters                | Values                      |
|---------------------------|-----------------------------|
| Dimentions: Diameter external; internal, length (cm) | 45x29x31                  |
| Density, g/cm³            | 6.2                        |
| Open Porosity, %          | 16                         |
| Hardness HB, MPa          | 700                        |
| Strength at radial compression, MPa | 420          |
| Microstructure            | Perlite, Sulfides, Pores;   |
To ensure the self-lubricating effect, the sleeves were impregnated with hydraulic oil. Thus, even at the beginning of the movement between the shaft and the bearing, it should be an oil film creating favorable operating conditions.

In the study [9] a new lubricating compositions for impregnating in sintered bodies had been used. Such compositions consist of basic mineral oil with addition of 4 wt.% of layered tungsten dichalcogenides (WS$_2$ and WSe$_2$) nanoparticles, which were ultrasonically dispersed. In the recent study, the bushings were impregnated with transmission oil of Russian grade MS-20, as well as the same oil with additions of tungsten disulfide WS2 and diselenide WSe2 nanoparticles. Tungsten disulphide nanoparticles have spherical shape with the diameter of 30-50 nm, and diselenide nanoparticles have a flat shape with the mean dimensions of 5x70 nm as shown in the Fig.2.

![TEM micrographs of WS2 (a) and WSe2 (b) nanoparticles.](image)

Tribological testing of the product was provided. Sintered bushings impregnated with commercial oil and with suspension of nanoparticles were tested in the spinning friction conditions in the couple with bearing steel at the load of 210 N and spinning rate of 200 rpm.

Testing was carried out by using the friction machine PBD-40, developed in Saint Petersburg Polytechnic University. A cylindrical specimen of bearing steel (SHKh-15 in Russian grade) of 10 mm in diameter, was clamped in the spindle of the friction machine. The test bushing was placed under the sample and fixed in a special clamp on a rotating base, which was kept from turning by a metallic wire fixed on the strain gage. Samples were brought into contact with a normal load of 210N. Further, the process of rotation of a spindle with a cylindrical sample with a rotation frequency of 200 rpm was started. The time of one test was 1000 s.

3. Results and discussion

The dependences of the frictional torque of “roller-ring” rotation on time for bushings impregnated with MS-20 oil, as well as with lubricant compositions, are shown in Fig.3. In all cases, the straining occurs in the second sec of the experiment, the moment of friction is equal to 0.12±0.1 Nm for all lubricating compositions. The identity of the moments of friction and the intervals of time before straining can be related to the identity of the initial friction conditions expressed, primarily in the overlapping of pores with oxide films of a certain thickness.

The graph (Fig. 3) also shows that the dependence of the frictional torque on time for bushes impregnated with MS-20 oil and lubricating composition with WSe2 have a “jumps” in the frictional moment, which may be associated with contact and destruction of ungreased oxide films. Then after extruding from the pores of the lubricating oil, the torque fluctuations decrease. Since the nominal contact area is variable, new areas with oxide films are involved in the friction process, which also break down, opening the way to the lubricating oil on the surface.
Figure 3. Dependence of the frictional torque versus time when testing a sleeve impregnated with mineral oil MS-20 and lubricating compositions containing 4wt.% of WSe$_2$ and WS$_2$.

The dependence of the frictional moment of roller-ring rotation on time for a bushing impregnated with a lubricating composition oil MS-20 + 4% WSe$_2$ and MS-20 + 4% WS$_2$ is shown in Fig.3. For these compositions, after friction, a sharp decrease in the frictional torque occurs due to the extrusion of the lubricant composition onto the friction surface and the interaction of the nanoparticles introduced into the lubricant compositions with the friction surface. On average, the frictional torque was equal to ≈0.056Nm and ≈0.067Nm for oils modified with selenide and tungsten sulfide nanoparticles, respectively.

The most stable moment of frictional friction was shown by a bushings impregnated with a lubricating composition MS-20 + 4% WS$_2$. It can be noted that for the lubricant composition containing spherical nanoparticles of tungsten disulfide, after characteristic breaking down in the beginning of friction, characteristic “jumps” in the moment associated with the destruction of the oxide film do not appear. This can be due to, on the one hand, small thickness of oxide film, and on the other hand, due to spreading the lubricant composition squeezed out on the local site over the surface of the oxide film, which has not yet been destroyed, but which comes into contact. In this case, the spherical shape of the introduced particles begins to play an important role.
4. Conclusions
Based on the conducted express study we can conclude:

The test bushings with friction on the flat base of steel cylinder have close moments of friction at brakedown and time intervals before stationary friction start, which is related to the identity of the initial conditions of friction, as well as to overlapping pores with oxide films of a certain thickness.

When the bushings is impregnated with the lubricating composition MS-20 + 4% WSe2 and MS-20 + 4% WS2, the average frictional torque decreases by ≈53% and ≈44% respectively in comparison with the bushings impregnated with MS-20 lubricating oil.

The most stable moment of friction was shown by bushings impregnated with lubricating composition MS-20 + 4% WS2, that may correspond with the shape of nanoparticles.

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