Mixture substantiation of the powder composition for bearing units seats restoring of rolling bearings

E Yu Lyakhov, V A Zorin
Moscow Automobile and Road Construction State Technical University (MADI), 64, Leningradsky Prospect, Moscow, 125319, Russian Federation.

E-mail: zam-upr@gmail.ru, madi-dm@list.ru

Abstract. The article substantiates optimal and most promising composition of a powdery thermoplastic composite polymer material used to restore worn-out rolling bearing units seats with combination of electrostatic and vibro-vortex coating methods. A laboratory installation for applying and forming coatings by a chamber electrostatic method is presented, with the help of which coatings were applied to steel 45 and AL-4 aluminum samples, after which they were melted in an oven at a temperature of 220 °C for 10 minutes. Based on the studies carried out, the optimal composition of the powdery polymer composition was determined: epoxy oligomer - 32 ... 40 %, powdered glass fiber - 9.8 ... 11.6 %, the rest - polyamide 12. At the same time, the coatings obtained from this composition on aluminum alloys substrates have insufficient adhesive strength. Therefore, the search for ways to increase it is relevant, and the solution of this issue will create a reliable technology for restoring rolling bearings seats.

1. Introduction
The operation of cars and road-building machines is the longest period of product's life cycle, realizable capabilities completeness of machines during operation is determined by adopted maintenance and repair system, technological equipment used, operating materials quality, qualifications and motivation of the service personnel, and adopted technological processes of restoring operability.

Bearing units state of the rolling bearings has a significant impact on automotive and road construction equipment durability and performance, operating modes of which are characterized by specific operating conditions [1].

Experience of using automobile and road-building equipment, numerous studies carried out in the field of durability and various operational properties studying of bearing assemblies show that wear or linear dimensions and geometric shape inconsistency of the seats with regulatory requirements lead to coordinated arrangement violation of all parts of mechanisms. As a result, the static and dynamic loads on the mechanisms parts increase, wear intensity of rolling bearings seats and elements increases. A great influence on accuracy of mechanisms parts arrangement during their operation is exerted by the one-sided nature of the loads taken by rolling bearings, which leads to a relative body parts walls deformation due to changes in residual linear stresses.

Optimal polymer composition choice for bearing assemblies restoration should be based on the theoretical foundations of viscoelastic bodies destruction processes under the mechanical loads action [2].

Literature data analysis shows that powdery thermoplastic polymers and compositions based on them are the most suitable for restoring bearing seats, and a directed change in polymers properties during their processing by composition mixture optimizing, intensifying the adhesive joints formation is one of...
the most expedient ways of creating coatings with high and stable physical and mechanical properties.

2. Problem formulation

Electrostatic is the most promising method for applying powders to the bearing seats repairable surfaces. It is based on the ability of polymer powders to acquire an electrical charge when placed in a high voltage electrostatic field and then transferred to the part to be coated. The method is characterized by high productivity, possibility for complex mechanization and automation of the process, ease of adjusting coating thickness, allows you to cover products made of heterogeneous materials. With a combination of electrostatic and vibro-vortex (chamber) methods, coatings with a thickness of 1 ... 2 mm can be obtained [3].

However, the existing mixture compositions for chamber electrostatic method do not meet modern repair production requirements for coatings used to restore rolling bearings bore holes, and existing equipment does not allow obtaining uniform coatings over the hole entire surface. It is recommended to use polyamide coatings to restore parts that perceive vibrational loads and work in aggressive environments [4].

Powders based on polyamide 12, a polymer material with a complex of valuable physical, mechanical, technological and operational properties, are promising.

The coatings obtained from P-12 have satisfactory wear resistance, a wide range of operating temperatures (-20 ... + 100 °C), and absorb shock loads well [5]. However, particles of polyamide powders when heated poorly retain an electric charge due to a decrease in electrical resistance, which complicates obtaining coatings process in an electric field. Polyamide coatings have significant shrinkage and high internal stresses, and their adhesion strength is insufficient [3]. These features limit the possibility of their use as coatings for restoring bearing assemblies seats.

Nowadays, the industry has mastered various epoxy powder polymers production, which are used mainly to create protective and decorative coatings. These powders, in contrast to polyamide ones, are charged faster in an electric field and more fully concentrate the charge. The coatings obtained from them have good adhesion strength and hardness [6], but it is impossible to use these coatings in their pure form to restore the mounting holes, in view of their high fragility and low wear resistance.

It is possible to assume that polyamide coatings properties can be purposefully changed by introducing epoxy oligomers into them. This should help, on the one hand, improve composition powder particles electrodeposition, adhesion strength increase, on the other hand, the polyamide should give the coatings increased impact strength and flexibility [4]. The hardness, wear resistance and dimensional stability of coatings can be increased by filling the composition with crushed glass fiber [7].

Based on available data analysis, it can be concluded that polymer composition creation based on polyamide P-12 and an epoxy oligomer using crushed fiberglass as a filler will make it possible to obtain coatings on worn-out holes of bearing assemblies with necessary physical and mechanical properties.

Bearing assemblies operating conditions and repair companies experience show that coatings used to restore the seats of rolling bearing housing parts must provide the following indicators:

- have high wear resistance during assembly, operation and disassembly;
- have high impact strength (not less than 4.6 N·m);
- have a high ability to electrodeposition (not less than 150 g / m²).

Thus, the aim of the study is to develop a powdery polymer composition for obtaining coatings on bearing assemblies bore by electrostatic chamber spraying method.

3. Materials and methods

The research was carried out in two stages. At the first stage, composition components were chosen and dependence of the physical and mechanical properties on components percentage was studied. At the second stage, the search for the optimal mixture composition was carried out.

Filler effect on composition quality is the least predictable. Therefore, studies were carried out for five levels of filler content.

As criteria for mixture optimizing of the composition, limiting powder electrodeposition, coating impact strength, and repaired bore holes wear resistance during mounting and dismounting of bearing
assemblies are taken.

Powder composition was prepared by dry mixing in a ball mill for 1 hour at a drum rotation speed of 80 ... 100 m$^{-1}$, followed by sieving through a vibrating sieve with a mesh № 0.2.

Composition mixture: polyamide 12, epoxy oligomer P-EP-219 and crushed glass fiber.

The composition was applied by a chamber electrostatic method (Fig. 1), followed by reflow in a thermal furnace at a temperature of 220 °C for 10 min.

The adhesion strength was determined for coatings applied to steel 45 and AL-4 specimens according to the procedure shown in Fig. 2, impact strength - for coatings applied to flat samples. Fittings wear resistance was assessed by the number of assembly-disassembly cycles of mates with 20 μm initial interference until the zero position of the tested mates was reached, i.e., until a constant bore size is achieved.

**Figure. 1.** Laboratory installation scheme for applying and forming coatings by a chamber electrostatic method: 1 - electromagnetic vibrator; 2 - filter drier; 3 - manometer; 4 - fluidized bed bath; 5 - heater; 6 - part to be coated; 7 - polymer coating; 8 - a ring with an electrode grid; 9 - porous partition; 10 - waveguide; 11 - ultrasonic generator; 12 - magnetostrictive transducer; 13 - cascade generator; 14 - thermostat; 15 - vibrometer; 16 - oscilloscope.
4. Results and discussion
As a result of experimental data analysis, the dependence of the physical and mechanical properties on percentage of constituent compositions was obtained:
- with an increase in the amount of P-EP-219, powder adhesion strength and electrodeposition increase, other indicators decrease;
- with an increase in the amount of finely dispersed glass fiber, wear resistance increases during assembly, operation and disassembly;
- mixture composition affects the impact strength ambiguously.

The search for optimal composition mixture showed that maximum value for assembly and disassembly cycles of joints with an initial interference of 20 μm until reaching the zero position is 8, and impact strength did not decrease below 4.6 N·m. Thus, the optimal composition mixture is: epoxy oligomer - 32 ... 40%, powdered glass fiber - 9.8 ... 11.6%, polyamide 12 - the rest.

Physical and mechanical properties of the composition for constituents limiting content conditions are shown in Table 1.
Table 1. Physical and mechanical properties of powders and coatings obtained from the recommended composition

| Composition mixture | Physical and mechanical properties | Adhesion strength, MPa |
|---------------------|-------------------------------------|------------------------|
| Polyamide 12        | EDP^a, g/m² | n^b | y^c, N·m | steel 45 | AL4 |
| P-EP-219 fiberglass | 162 | 8 | 4.77 | 29.2 | 18.16 |
| 66.4                | 32 | 11.6 | 174 | 8 | 4.6 | 29.35 | 18.15 |
| 58.4                | 40 | 11.6 | 162 | 8 | 4.9 | 28.86 | 20.16 |
| 68.2                | 32 | 98 | 174 | 8 | 4.73 | 30.85 | 21.07 |
| 60.2                | 40 | 9.8 | 174 | 8 | 4.73 | 30.85 | 21.07 |

^a Powder electrodeposition, g/m²; ^b Number of assembly-disassembly cycles of joints with an initial tension of 20 microns until reaching zero position; ^c Impact strength N·m;

5. Conclusion

Thus, the developed composition ensures coatings production with high wear resistance (n = 8), good powder electrodeposition of the (EDP 162-174 g/m²) and high impact strength (y = 4.6-4.9 N·m). These indicators make it possible to use the composition for restoring worn-out rolling bearing seats. However, it should be noted that the coatings obtained from this composition on aluminum alloy substrates have insufficient adhesive strength. Therefore, the search for ways to increase it is relevant, and the solution of this issue will create a reliable technology for rolling bearings seats restoring.

References

[1] Zorin V A, Lyakhov E Yu 2018 Durability analysis of bearing seats restored with polymer materials Interstroymech-2018 337–342
[2] Lyakhov E Yu 2020 Modeling of surfaces fatigue fracture processes of automobiles bearing units restored with polymer materials Herald of the Moscow Automobile and Road Construction State Technical University (MADI) 3 10–12
[3] Yakovlev A D, Dzor V F and Kaplan V I 1979 Powder polymeric materials and coatings based on them (Leningrad: Chemistry)
[4] Bazhenov S L 2014 Mechanics and technology of composite materials: Scientific edition (Dolgoprudny: Intellect)
[5] Kolyasko I V 1980 Research and development of technology for restoring parts agricultural machinery with polyamide coatings: Ph.D. thesis in Engineering Science (Moscow)
[6] Dudchak V P 2003 Theoretical prerequisites for adhesive strength study of polymer composite coatings with a base Electro material processing Vol 39 1 27–30
[7] Baurova N I and Zorin V A 2018 Polymer composite materials application in machinery (Moscow: INFRA-M)