The technique of automated applying of polymer coatings used for repair of tractor parts

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Abstract. Restoration of case parts of machines significantly reduces the cost of their repairing. The present paper proposes a method for restoring case parts using the repair size method. Depending on wear degree, the fitment holes are bored to three repair sizes. The prepared hole is inserted with a new bearing, the outer ring of which is covered with a polymeric coating of the appropriate thickness ensuring the fixity of the joint. As a result of theoretical studies, the model was obtained for the formation of a uniform polymer coating on the outer surface of a rotating cylindrical part. The facility and technological equipment were developed for applying a polymer coating of F-40C elastomer solution onto the outer surface of the rotating bearing. The facility includes screwing lathe 1K62, centering drift pin, bath and magnetic holder MV-V. The holder is designed for mounting a bath filled with polymer solution and its plunging movement when rolling bearings are immersed in polymer solution. The drift pin serves for centering and assembling bearings. The assembled drift pin is inserted into the chuck of the machine rotating the pin when applying polymer coating. The screwing lathe 1K62 is equipped with an INNOVERT frequency converter of H3400A05D5K type, which allows adjusting infinitely the spindle speed from 0 min⁻¹. The paper presents the results of experimental studies on the F-40C elastomer shrinkage, the parameters of the mode of immersing parts into its solution, the dependence of the geometric parameters of the formed polymer coating on the components of application and adhesion modes for polymer coatings based on F-40C elastomer solutions of different viscosity. The acceptable thickness of the polymer coating of elastomer F-40C on the bearing 209, ensuring the non-failure operation of the restored seating with a cyclic radial load of 20 kN is 0.1 mm.

1. Introduction
Case parts are basic durability components determining the longevity of the machine. The wear of fitment holes in a gear-box casing leads to the misalignment of bearing rings, shafts with gears, their increased wear and sharp resource reduction. Fitment holes of case parts are restored by installing an additional part, electric arc welding, electric contact welding of steel tape, ironing or chrome plating [1-4]. However, these methods do not provide fretting resistance [1-2] of repaired fitment holes. Restoration ways with applying of polymeric materials eliminate fretting corrosion and increase the life of case parts and bearing units [5-8].

The development of the domestic chemical industry is accompanied by the permanent release of new promising polymeric materials for various purposes. Favorable environment is being formed for the development of high-performance restoration technologies providing the increase in the life of case parts, reliability of agricultural equipment and reduction of technical service cost.
The methods of restoring fitment holes with the use of polymeric materials [5-8] are defined by simplicity and low cost, exclude the occurrence of fretting corrosion, increase the life of case parts and bearing units. The analysis showed that the most technologically advanced method of restoration is the application of a polymer coating on the worn surface of fitment holes. However, known technologies imply the manual performing of this operation and do not exclude shrinkage of the polymer material during curing, which affects the dimensional accuracy of the restored holes.

It is proposed to restore the fitment for bearings in case parts using the repair size method. Depending on wear, the fitment holes are bored to three repair sizes

\[ D_{\text{rep}1} = D_{\text{nom}} + 0,1\,\text{mm}; \quad D_{\text{rep}2} = D_{\text{nom}} + 0,15\,\text{mm}; \quad D_{\text{rep}3} = D_{\text{nom}} + 0,2\,\text{mm}, \]  

where \( D_{\text{rep}1}, D_{\text{rep}2}, D_{\text{rep}3} \) are for first, second and third repair sizes; \( D_{\text{nom}} \) – nominal diameter of a fitment hole.

The prepared hole is inserted with a new bearing, the outer ring of which is covered with a polymer coating from solution of elastomer F-40C of appropriate thickness, ensuring the fixity of the joint.

As a result of the analysis of automated methods, it is proposed to apply a coating by dipping a bearing in a bath filled with solution of polymeric material. The coating should be formed uniformly due to the rotation of the bearing and the flow of the polymer solution under the action of gravity.

As a result of theoretical studies [9-11], the authors prepared a model for forming a polymer coating on the surface of the outer ring of a rotating bearing. For the technology of automated coating on the surface of the outer rings of bearings, new tooling is needed, as well as comprehensive experimental studies.

The purpose of the research is to develop tooling and execute experimental studies of automated coating of rolling bearings with F-40C elastomer solution.

2. Materials and methods

To study the shrinkage of polymeric coatings, elastomer F-40C solutions with the following viscosity parameters were used: \( \nu = 3157; \ 329 \) and \( 160 \) mm\(^2\)/s. The viscosity was provided by adding acetone to the concentrated F-40C elastomer solution. The viscosity of F-40C elastomer solution \( \nu = 3157 \) mm\(^2\)/s was controlled by a viscometer VNZH (GOST 10028-81E), \( \nu = 329 \) and \( 160 \) mm\(^2\)/s by a viscometer VPZH-2 (GOST 10028-81). Cured films applied on a bedding of fluoropolymer served as samples. The films were rectangular, 60x15 mm.

The thickness of films was measured three times with an indicating snap gauge SRP-25 (GOST 11098-75). The shrinkage \( T \) of the material was calculated by the formula:

\[ T = \left(1 - \frac{h_{\text{film}}}{h_p}\right) \times 100\%, \]

where \( h_p \) and \( h_{\text{film}} \) are the thickness of a polymer film before and after curing, mm.

To study the parameters of the mode of immersing parts in solution of elastomer F-40C, the laboratory facility was elaborated, Fig. 1. It was mounted on the basis of the lathe machine 1K62 and includes a centering drift pin 1, a bath for polymer solution 2 and a magnetic stand 3.
Figure 1. Laboratory facility for the application of polymeric coatings.

Magnetic holder MV-V is designed to fix the bath and move it along the height when immersing the bearings into the polymer solution. The centering drift pin serves for centering and assembling bearings, fig. 2.

Lathe machine 1K62 is equipped with the common industrial frequency converter EI-7011, which enables the infinite adjusting of the rotation speed from 0 min\(^{-1}\). The number of revolutions of bearings in the bath filled with solution was \(N_{rev} = 1; 2; 3; 4; 5\) and 6. After lowering the bath, the bearings were rotating for 10 minutes at a temperature of 23 °C in order to polymerize the coating. After processing, they were kept for 24 hours at the temperature of 23 °C, and afterwards the diameter of the polymer coating and its average value were calculated using indicating snap gauge CP-100 (GOST 11098-75).

Figure 2. Centering drift pin: 1 - shaft; 2 - coupling bolt; 3 - packing nut; 4 - centering roller; 5 - washer; 6 - bearing.

When the dependence of the coating thickness on the number of applied layers of F-40C elastomer solution was under the study, films 60x15 mm in size served as samples. The number of layers was 3-4. The thickness of films was measured three times using an indicating snap gauge SRP-25.

Studies of the dependence of the coating thickness on the rotational speed of the bearing \(n\) were carried out on the laboratory stand (Fig. 1). The coating of F-40C elastomer solution with a viscosity of \(v = 3157\) mm\(^2\)/s was applied to bearings 209 at the rotation frequency of \(n = 1.0; 2.0; 3.0; 3.5\) and 4.0 min\(^{-1}\), viscosity of \(v = 329\) mm\(^2\)/s - 2.0; 3.5; 6.5; 8.0 and 10.0 min\(^{-1}\), viscosity \(v = 160\) mm\(^2\)/s - 3.5; 5.0; 7.5; 10.0 and 12.0 min\(^{-1}\).

Under the given frequency of rotation, bearings were immersed in the bath filled with solution of F-40C elastomer. The bath was lowered after three turns. The rotation of bearings continued for 10 minutes at the temperature of 23 °C in order to polymerize the coating. To calculate the out-of-roundness, the diameter was measured in mutually perpendicular planes, to estimate the tapering – it was measured in width at the start and end of polymer coating. Threefold measurements were with averaging values.

The adhesive properties of the material were evaluated by the bond strength with the metal during the ply separation of samples (GOST 21981-76). The coating of elastomer F-40C with viscosity of \(v = 3157; 329\) and 160 mm\(^2\)/s was applied. The strain of the polymer coating ply separating from the metal bedding was determined using a tensile testing machine IR5047-50.
The study of the durability of bearings fits of case parts restored with the use of elastomer F-40C was performed on a vibration table. The load on the bearings 209 was 20 kN. The operating time before the bearing outer ring was shifted inside the fitment hole was taken for the criterion of durability.

3. Results and discussion
Studies showed that the minimum shrinkage $T = 7\%$ has a coating from F-40C elastomer solution with viscosity $\upsilon = 3157 \text{ mm}^2/\text{s}$, fig. 3. With a decrease in the viscosity of F-40C elastomer solution, the shrinkage of the polymer coating after curing increases to 3.43 times, which is explained by the large amount of acetone evaporating from the solution.

![Figure 3. Shrinkage $T$ of applied polymer coatings from F-40C elastomer solutions of various viscosities: 1) $\upsilon = 3157 \text{ mm}^2/\text{s}$; 2) $\upsilon = 329 \text{ mm}^2/\text{s}$; 3) $\upsilon = 160 \text{ mm}^2/\text{s}$.

With the number of revolutions of a bearing in a bath with polymer solution of viscosity $\upsilon = 160 \text{ mm}^2/\text{s}$ increasing to three, the thickness of the polymer coating $h_c$ increases, fig. 4. With more revolutions, it stabilizes. A similar relationship was observed when bearings rotated in a bath with F-40C elastomer solution with viscosity $\upsilon = 329$ and $3157 \text{ mm}^2/\text{s}$.

![Figure 4. Dependence of the thickness of the polymer coating $h_c$ on the number of revolutions $N_{rev}$ of a bearing in the bath filled with F-40C elastomer solution: 1) $\upsilon = 160 \text{ mm}^2/\text{s}$; 2) $\upsilon = 329 \text{ mm}^2/\text{s}$; 3) $\upsilon = 3157 \text{ mm}^2/\text{s}$.

To obtain a polymer coating of sufficient thickness ($h_c \geq 0.5 \text{ mm}$), four layers should be applied from F-40C elastomer solution with viscosity $\upsilon = 160 \text{ mm}^2/\text{s}$, three layers with viscosity $\upsilon = 329 \text{ mm}^2/\text{s}$ or two layers of solution with viscosity $\upsilon = 3157 \text{ mm}^2/\text{s}$, fig. 5.
At the minimum rotational speed of bearings $n = 1; 2$ and $3.5 \text{ min}^{-1}$, the polymer solution of viscosity $3157; 329$ and $160 \text{ mm}^2/\text{s}$ respectively, partially drained from the surface of the outer ring. This is due to the fact that the geometric head pressure of upper layers of the liquid flow is much higher than that of the free-flow movement of underlying layers of the liquid flow, Fig. 6. Therefore, the thickness of the formed coatings is minimal: 0.13; 0.17 and 0.26 mm. With increasing rotation frequency of the bearing, the thickness increases.

The optimum rotation frequency of the bearing 209, which induces the formation of polymer coating of maximum thickness, is $3.0 \text{ min}^{-1}; 329 \text{ mm}^2/\text{s} - 6.5$ and $160 \text{ mm}^2/\text{s} - 7.5 \text{ min}^{-1}$ during applying polymer solution with the viscosity of $3157 \text{ mm}^2/\text{s}$. The further increase in the rotation frequency of bearing forwards the stabilizing of thickness of the polymer coating.

Adhesion is determined by wettability, which largely depends on the viscosity of adhesion. Therefore, to ensure a high value of this indicator, it is recommended to apply coatings from an F-40C elastomer solution with a viscosity of $\nu = 160 \text{ mm}^2/\text{s}$, fig. 7.
Figure 7. Adhesive strength of coatings F made of elastomer F-40C: 1) $v = 3157 \text{ mm}^2/\text{s}$; 2) $v = 329 \text{ mm}^2/\text{s}$; 3) $v = 160 \text{ mm}^2/\text{s}$.

Bearing fits of case parts restored with the use of F-40C elastomer having a polymer coating thickness of 0.1 mm remained functionally operative until the end of the test. The shift of the outer ring of the bearing in the fitment hole was not observed during stand tests lasted for 330 hours.

4. Conclusion

The facility for the automated applying of polymer coatings on outer rings of rolling bearings was developed.

To apply polymer coating of bearings, it is recommended to use elastomer solution F-40C with the viscosity of $v=160 \text{ mm}^2/\text{s}$, which ensures high adhesion of coating $F = 10.0 \text{ kN/m}$ and the coating thickness of up to 0.52 mm.

As the result of the study, the authors defined the appropriate mode of applying coatings from F-40C elastomer solution: the number of revolutions of a bearing in a bath filled with polymer solution is $N_{\text{rev}} = 3$, rotational speed of the bearing is $209 \text{ n} = 7.5 \text{ min}^{-1}$.

Bearing fits of case parts coated with F-40C elastomer are highly durable. Fitment holes of case parts having diametrical wear of up to 0.2 mm are recommended to be restored.

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