

INCREASING RELIABILITY OF BEARING UNITS OF AGRICULTURAL MACHINERY

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Abstract. The technical status of bearings is the main component, defining the intensity of the wear process of the surfaces of rotating parts and the working capacity of mechanisms as a whole. The operation conditions of the bearing units of agricultural machinery are characterized by abrasive and wet environment, and also by significant dynamic loadings, including shocks and vibration. Increase of reliability of the bearing units is provided due to favorable conditions of the part assembling, properties of their working surfaces, quality of lubricants and protection against the influence of the environment. On the basis of the analysis of the ball bearing modern designs and their surface treatment methods, there was found an opportunity for modifying the part initial material by covering them with films, different in the chemical content. The production technology of thin copper containing films on the surfaces of the rollers and racetracks of the bearing due to preliminary running in the technological environment is offered here. Improvement of mechanical and antifriction characteristics of the part surface, which is connected with the bearing ring, promotes decreasing of the wear intensity and increased endurance of the whole bearing unit. Modification of the part working surfaces of the bearing can occur by formation of covering films, containing copper or other plastic alloys (for example, zinc, tin, silver), if the necessary components are included into the lubricant. This is the basic principle for the development and application of the metal plated additives.

Keywords: bearing, modification, antifriction, treatment.

Introduction

Ball and roller anti-friction bearings are used in the units and mechanisms of agricultural machinery. The working conditions of the bearing compounds are characterized by variable speed, load and temperature regimes, high probability of occurrence of peak contact tension, negative effect of environment.

Operation of farm machinery is carried out under the influence of atmospheric and soil moisture, and high dustiness. During the movement of a tractor and agricultural equipment, the smallest soil particles are in the air in suspension. This is accompanied by accumulation of soil dust in the bearing lubricant, which leads to intensive abrasive wear of the rubbing parts.

One of the main factors, determining the bearing working conditions, is the specific load on the working surfaces of the rings and rolling elements. The type and intensity of wear of friction surfaces depend on the amount of loads and their associated contact tension. While the contact tension up to $1950 \text{ MN}\cdot\text{m}^{-2}$ there will flow the normal process of oxidative wear on the working surfaces, the intensity of which is minimal. With the load increasing fatigue wear occurs, leading to the destruction of the working surfaces. When the contact tension is more than $3920 \text{ MN}\cdot\text{m}^{-2}$, the bearing working period is very small till the fatigue damage occurs. A further increase of load angle is inadmissible.

Operation of units, containing anti-friction bearings, implies the presence of lubricants, which can be liquid, plastic or solid. Modern high-viscosity lubricants create an oil film of sufficient thickness that can sustain the contact load up to $2000 \text{ MN}\cdot\text{m}^{-2}$ without tearing of the friction surfaces. The best lubricating characteristics, as a rule, tend to have liquid materials. But for their delivery and retention in the areas of friction, closed cavities, forcing equipment, pipeline and filtration systems are required. This leads to complication and rise in the price the machinery constructions, therefore, is rarely used in agricultural machinery. That is why the bearing units with plastic lubricant are used most widely. This lubricant is designed for the entire life of the machine, or it is intended to substitute during the planned service work.

It was found that breakage of operating bearings might be caused by the following reasons: an increase in the clearance beyond the limit value – 65 ...75 %, malfunction of the fit compactness – 17... 21 %, crumbling of the working surfaces – 4..11 %, breakage of the bearing parts – 5 ...9 %.

Thus, anti-friction bearings, being effective means for friction decrease in machinery and mechanisms, have not high reliability themselves, especially while operating in the heavy-loaded units.

Materials and methods

Improvement of reliability of the agricultural machinery bearings can be achieved by design, technological and operation methods. Under constructive methods we mean optimization of the shape of solids of revolution, their movement trajectory, presence of zones of unloading, improvement of compaction and methods of the lubricant delivery into the loaded zones. The technological methods are directed to improve the manufacturing operations of individual parts, to improve the shape accuracy and cleanliness of the surface treatment, a choice of proper materials, both for the rings and solids of revolution, and for the separator and sealing devices. The initial material of the parts could be improved by modifying the working surfaces. The working life of the bearings depends greatly on high accuracy of the assembly, installation and adjustment of the compounds. The operation methods involve the possibility of providing the high-quality burn-in of the working surfaces and their remetallization, due to the presence of chemical elements of plastic metals in the lubricant (Fig. 1).

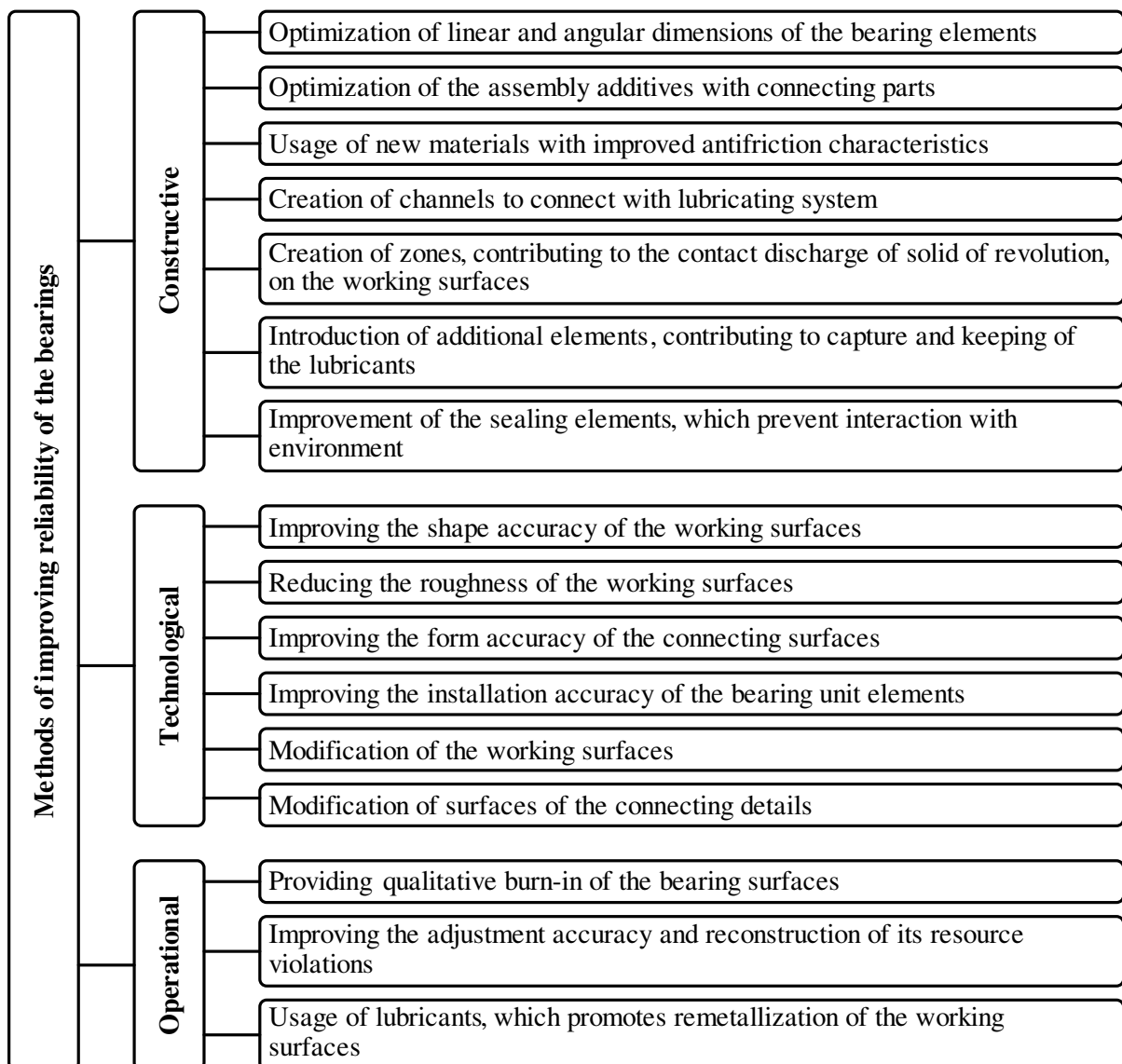


Fig. 1. **Methods of improving reliability of bearings**

Such technological treatment methods, as modification of the bearing working surfaces and connecting to them the surfaces of the parts, can be considered the most acceptable for the main and heavy-loaded bearing units. The advantages of these methods include the low cost of funds and materials, as well as the ability to perform these operations both in the factory before the mechanism assembly and the repair and servicing facilities for resource recovery of used vehicles.

It may seem strange, but modification of the mentioned bearing surfaces should not be directed to increase their hardness. Conversely, excessive hardness of the surface has a tendency to provide a crack or a complete destruction of the part at presence of alternating loads with high peak values (Fig. 2).

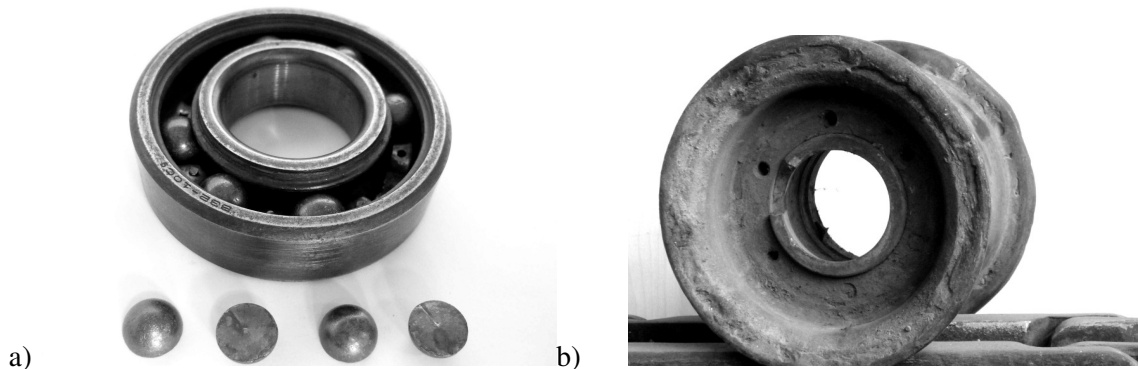


Fig. 2. Examples of bearing part destruction in units of agricultural machinery in excess of admissible contact tension: a – solids of revolution destruction; b – destruction of the outer ring

Back to front, the positive effect is achieved with the help of creation of damping layers of soft plastic metals. The most common material for modification of steel surfaces is copper and its alloys. Electrochemical and friction-mechanical methods should be used for the application of these materials. Usage of the latter method in its different variants is directed to the final anti-friction non-abrasive treatment of the parts (FANT) [1].

Results and discussion

The proposed method for finishing treatment of the radial-stop tapered roller bearings before operation is as follows. Several bearings (from 2 to 6) of one size are simultaneously exposed for the treatment. The number of bearings must be even to get an opportunity for pairwise fitting of their outer rings in the ball races. In the axial direction of the force acting on the inner ring of the bearing, the radial reaction will occur on the contact line of tracks and solids of revolution of both bearings. The ball race, with the bearing outer rings installed inside it, is unable to rotate in the bath, but has a possibility of vertical movement due to the presence of the guide bushings. The inside cylindrical surface of the bath has lengthwise grooves. Their location and dimensions correspond to the location of the guide bushings on the ball races (Fig. 3)

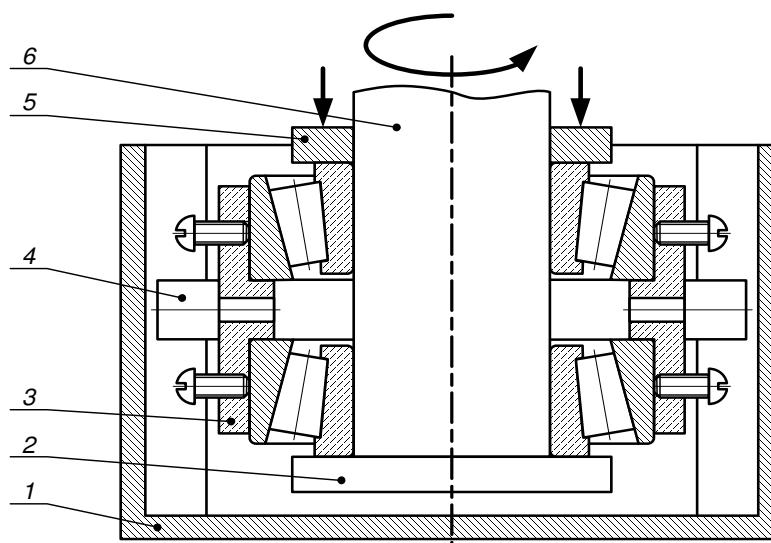


Fig. 3. Device for finishing treatment of bearings: 1 – bath; 2 – thrust collar; 3 – ball race; 4 – guide bushing; 5 – push washer; 6 – drive shaft

The assembled set of bearings is placed inside the bath, which is filled with technological medium containing glycerin, superdispersed copper powder, copper chloride, tin chloride and ferric chloride. The presence of superdispersed copper powder contributes to rapid destruction of the oxide films on the treated surfaces and forms the copper saturated coating. The presence of tin, iron and copper salts ensures increase of wear-preventive and antifriction properties of the obtained coatings.

Turning on the rotation actuator of the machine the device first rotates the bearings without application of axial load. In this case there active mixing of particles takes place. The particles of superdispersed copper powder fall between the tracks and the bearings solids of revolution. As a result, mechanical and chemical removal of oxide films takes place. Dissolution of the particles with forming copper ions, which sink on the working bearing surfaces in the form of coatings, also occurs there. These coatings become additionally saturated with solutions of metals, recovered from the corresponding salts.

After application and smooth increase of the load, the bearing rotation continues for another 15-20 minutes. It is accompanied by compaction and increase of the coating thickness. When certain thickness (0.5 – 3 micrometer) between the processes of formation of the coating and its wear is obtained, dynamic balance takes its place, and thickness growth of the coating stops. After that, the machine rotation actuator should be disconnected; the driving shaft with a set of processed bearings should be taken out of the bath. Then the driving unit is to be disassembled and bearings are removed from it. The bearing parts are washed and coated with the working grease.

In comparison with the known technologies [2; 3] the proposed method allows to increase the productivity of the treatment by improving the content of the technological medium and by the treatment modes, as well as by simultaneous treatment of several bearings.

Increased durability of the bearing can also be achieved due to optimization of its assembly fits with the joined parts. It is known, that the main types of loading on the bearing rings is circular, and local. In this case it is recommended to connect the circular loaded ring with interference fit. As for building-up of the local loaded ring with a connecting piece, there the fit with clearance should be used, because it provides periodic turning of the ring and moves the loaded sector of the track. However, excessive weakening of the fit can cause intense rotation of the ring relative to the part, the appearance of furrows, grasps, up to the welding of two parts caused by the friction temperature.

To improve the conditions of assembly and durability of the bearing unit it is recommended to modify the fitting surface of the piece in the installation place of the locally loaded bearing ring, using coating of ductile metals (copper, tin, zinc, nickel, lead, etc.) with the thickness about 100 ... 400 nanometer, with the help of the finishing anti-friction non-abrasive treatment [4]. The coating layer with its thinness contributes to changing the physical and mechanical properties of the surface area of the treated piece material. The pre-assembly treatment ensures increase of the surface hardness and furrow resistance of the treated piece. It also ensures reduction of stress concentration on the joined surfaces, and ensures reduction of the friction coefficient between them. Thanks to this, decrease of the assembly clearance size is permitted, while the ability of the ring periodic turning, relative to the piece of the machine at work is retained.

In order to intensify the process of formation, raising the thickness and durability properties of the protective films for restoring of rubbing surfaces during the bearing units operation, it is necessary to use a metal plated additive for lubricants.

The additive action mechanism is to activate nanocomplexes of kinetic and potential energy of friction. At the same time a nanocrystal self-restoring protective film with the minimal friction and wear coefficient is formed from the additive active components and the wear particles on the rubbing surfaces. The additive promotes restoring of nano- and micro-defects on the friction surfaces and their working capacity. It is most effective in the conditions of boundary friction under high loads and sliding speeds, when the temperature friction increases, under "oil starvation", typical of worn rubbing compounds of machinery with large service life, running-in mode and overloading.

The author carried out research in the metal plated additive, containing neutralized oleic acid, its salts of plastic metals: copper, tin, nickel, and super dispersed powders of these plastic metals. The additive was introduced into the plastic lubricants in the amount up to 10 % of the weight and is thoroughly mixed before introduction into the friction zone [5; 6].

Testing of the developed additive in the soft grease made it possible to find out reduction of the radial clearance in the bearings due to formation of the metal-plated coating with the thickness of 3 to 5 microns on the working surfaces. This coating reduces the radial clearance in the bearing on 12 – 20 microns.

The preparation provides significant increase of the part wear resistance, decrease probability of scarring on rubbing surfaces, reduction of duration and improving the quality of running in the rubbing surfaces, effective resistance to scarring and decreasing of contacting surfaces pitting in heavy loaded rubbing pairs, due to the formed nanostructures that showed damp fire properties, decreasing temperature of the operating lubricant, noise level and vibration of the bearing units.

Conclusions

As a result of the anti-friction finishing treatment, the covered layer of the solid lubricant with its own thinness contributes to changing the physical and mechanical properties of the surface area of the ring material and the bearing solids of rotation. In addition, this layer acts as a dampener and reduces the contact stresses under high loads. It promotes increase of the bearing durability.

In preparation for the assembly with the locally-loaded ring of the roller bearing, it is recommended to put the part surface to the finishing anti-friction non-abrasive treatment. There rubbing by copper, brass or molybdenum rod in the technological solution medium takes place under pressure. The technological solution medium contains salts of ductile metals and ensures transfer of the rod material onto the surface under treatment. The proposed method of assembly makes it possible to perform the part connection with the bearing ring along the transitional fit. It provides an opportunity for mutual turning of the parts for all points of the track of the locally loaded bearing ring to take in turn the radial load. Giving improved mechanical and antifriction properties to the part surface which is connected with the bearing ring promotes the intensity reduction of its wear and increases the durability of the bearing assembly.

In the operation of the mechanism lubricants containing the metal plated additive should be used. Due to the development of the damping properties formed by nanostructures a significant increase in wear resistance is ensured. The damping properties also promote reduction of the furrow occasion and pitting of the contacting surfaces. However, the obtained layer is considered remetallizer of the worn surface.

References

1. Garkunov D. N. Finishing anti-friction non-abrasive treatment of the parts friction surfaces / Repair, Restoration, Modernization. – 2009. - №2, – pp. 10 – 17. (In Russian).
2. Kremeshny V. M., Andropov S. P., Astakhov V. V. etc. The Way of the Roller Bearing Treatment before Operation. - The Certificate of Authorship №1196552 Soviet Union MPK⁷ F16C 33/66, C23C 17/00. Statement 08.02.1984; Published 07.12.1985. (In Russian).
3. Semkin K. D., Chernevsky L. V. Bearing with Constant Lubrication Layer and the Way of Its Preparation. - Patent №2095653 Russian Federation, MPK⁷ F16C 33/00, 33/66. Statement 25.09.1996; Published 10.11.1997. (In Russian).
4. Inshakov S. V., Balabanov V. I., Ishchenko S. A. etc. Method of connecting the component with the ring of bearing - Claim for the invention №2010124710 Russian Federation, MPK⁷ F16C 33/00.– Statement 16.06.2010; Published 27.12.2011. (In Russian).
5. Inshakov S. V., Ishchenko S. A., Balabanov V. I. etc. Improvement of the lubricants quality / Machinery in Agriculture. – 2011. - № 4, – pp. 24 – 28. (In Russian).
6. Inshakov S. V., Borzykh I. V., Balabanov V. I. etc. Change of transmission lubrication properties due to introduction of the metal plated additives // INSYCONT-2010 Energy and environmental aspects of tribology: 8th International symposium (07 – 09 July 2010 y.) – Poland, Cracow, 2010. – pp. 18 – 21.