VOL. 13, NO. 10, MAY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

INFLUENCE OF NANOCOMPONENT GREASE ON OPERATION LIFETIME OF ROLLER BEARINGS

V. V. Safonov, A. S. Azarov, V. V. Venskaytis, S. Y. El'kin and A. A. Protasov
Saratov State Agrarian University, Saratov, Teatralnaya Ploschad, Russia
E-Mail: vv.safonov@bk.ru

ABSTRACT

Literature review revealed that operation lifetime of roller bearings was a factor determining reliability of automotive machinery. On the basis of analysis of existing methods of improvement of lifetime of roller bearings a promising trend was determined: modification of greases by nanosized powders of various metals and their compounds. The selected variant was based on possibility to improve service properties of roller bearing surfaces without application of expensive equipment and tools. This method was implemented at the stage of operation during actual adsorptive, chemosorptive and tribochemical processes in the friction areas with nanosized components. Grease was experimentally developed on the basis of Lithol-24, Russian standard GOST 21150-87 with nanosized metal particles obtained by plasma recondensation. Comparative tribological experiments of commercial grease and nanosized grease demonstrated efficiency of the latter. Commercial tests of roller bearings with the developed grease had been carried out. The acquired experimental results demonstrated that gamma-percentile life of the bearings operating with the developed grease was by 2.8 times higher than that of the bearings operating with the commercial grease.

Keywords: operation lifetime, bearings, grease, nanosized powders.

INTRODUCTION

Mechanization in agricultural industry is based on energy-intensive high-efficiency machinery. Agricultural activities are characterized by seasonal loads, which requires for high reliability of all units and systems.

At present 20-30% of all agricultural activities are comprised of transportation. Reliability of vehicles depends significantly on working efficiency of chassis units and facilities. Analysis of reliability of KamAZ vehicles detected that 16-22% of total failures are attributed to chassis. One of main reasons of low reliability of this system is low lifetime of wheel hub roller bearings [1-3], which causes increase in operation expenses and decrease in safety of road haulage. Such bearings are expensive and non-recoverable elements [4]. High cost of hub bearings together with low lifetime require for improvement of their service life which can decrease significantly operation expenses and prime cost of agricultural products.

LITERATURE REVIEW

The existing methods increasing lifetime of roller bearings can be subdivided into three groups: designing, engineering and operational.

Designing and engineering methods together with their advantages require for high capital investments, thus increasing the cost of bearings [5]. Hence, peculiar attention is concentrated at operational methods, including modern lubricants with improved properties, modification of lubricants by means of special additives [6].

KamAZ wheel hub roller bearings are maintained by greases. Lithium greases are promising type of multifunctional antifriction materials [7]. Numerous types of greases of both Russian and Western origin are available in markets. Import greases in comparison with Russian products are often characterized by better tribological properties, though; they are usually more expensive [8]. This can be attributed not only to improved oil carrier and thickener type but also to composition of additives.

In terms of applicability the highest interest is attracted to powdered metal additives. Popularity of metal components in additives to greases can be explained on the basis of wear analysis of working surfaces of bearings.

It follows from the description of fatigue wear in [9] that at initial stage of fatigue wear cracking is naturally hindered. This is caused by the fact that dispersion of wearing surfaces according to fatigue mechanism is accompanied by formation of dispersoid with high free energy. Dispersoid attempts to decrease it and this stipulates compaction, conglomeration and sintering of wear products initiated by friction heating and contact pressure. Therefore, during friction in greasing medium these particles are sintered into multiphase compacted film characterized by fine crystalline, partially amorphous structure. The sintered films prevent direct contact between wear surfaces, possess high contact strength, decrease pressure in actual contact area, promote localization of plastic deformation due to high plasticity, and finally decrease wear of parts retaining integrity of their working surfaces.

Taking into account the above description it is possible to assume that it is possible to form surface films with superior tribological properties by means of forced addition of high active nanosized powders (NSP) of metals and their compounds to basic grease, their composition can be selected experimentally with consideration for engineering peculiarities of friction coupling and operational conditions.

Therefore, the following purpose was formulated: to develop composition of nanosized grease and to carryout complex tests in order to evaluate its influence on lifetime of automotive roller bearings.

VOL. 13, NO. 10, MAY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

METHODS AND MATERIALS

The studies were performed in the following sequence:

a) preliminary laboratory tests of greases prepared with NSP of metals and their compounds;

b) selection of the most efficient NSP and optimization of nanocomponent grease;

c) comparative laboratory tests of the developed and basic greases;

d) operational tests.

Analysis of the existing production technologies of NSP of metals and their compounds [10-12] aiming at their use for development of efficient grease revealed the method of plasma recondensation (Russian patent No. 2068400). An advantage of this method is possibility to dope NSP of pure metals and alloys with various elements upon their production. The obtained powdered particles are nearly of spherical shape, particle size: 10…30 nm, specific surface area: 100…150 m^2/g.

Experimental greases in this work were prepared on the basis of Lithol-24, Russian standard GOST 21150-87, and NSP of the following metals and alloys: Ni, Fe, Zn, Cu-Sn, Al-Pb, Cu-Pb, Fe-Ni, Fe-Zn. NSP materials were selected on the basis of published data [6] and previous studies [13]. Experimental greases were prepared by intensive mechanical dispersing of the considered powders in basic grease.

Preliminary experiments, complete factorial experiment and comparative experiments with the considered greases were performed using an MI-1M friction machine. A roller-on-roller friction couple was used for simulation of roller bearings' interaction.

The rollers were made of steel, grade ShKh-15, Russian standard GOST 2590-88 with the following properties: outer diameter - 50 mm, width of bottom roller - 12 mm, width of upper roller - 10 mm, roughness of wear surfaces R_a - 0.8 μm, hardness - HRC 60…62.

Efficiency of the considered greases was estimated by roller wear and moment of friction between rollers. During comparative tests the influence of greases on resistance of rolling surfaces against fatigue flaking was studied. The properties of experimental greases were compared with those of basic grease.

Testing modes (Table-1) were selected so that to obtain results with minimum labor and time consumptions.

Table-1. Laboratory experiments of the considered greases.

No.	Stages	Load, kN	Rotation frequency of lower roller, min^{-1}	Slipping in contact, %	Experiment duration, h
1	Preliminary laboratory experiments	0.8	500	10	3
2	Complete factorial experiment	0.8			3
3	Comparative experiments	1.25			6

Under actual conditions, operation of automotive roller bearings was influenced by the factors which could not be forecasted or simulated in laboratory tests. The influence of nanocomponent grease on lifetime of KamAZ wheel hub roller bearings was studied by comparative tests.

The tests were carried according to the test plan [NUT] including observation of *N* objects in the time *T*. Failed objects were not repaired and not replaced with new ones. The tests were terminated after expiration of test time or running time *T* for each non-failed object.

Twelve KamAZ-5320 vehicles were used in the tests. While testing, the bearing units of six vehicles were filled with Lithol-24 on the left side and with the developed grease in the right side. The remaining six vehicles: nanocomponent grease on the left side and Lithol-24 on the right side.

Running time *T* was set to 140 thousand km. The time of ultimate state of bearings with increment of 10 thousand km was visually estimated by fatigue flaking on roller working surfaces.

Lifetime of bearings in excess of the preset running time was estimated by the forecasting procedure in [14]. 90% lifetime of wheel hub bearings in this case was calculated as follows:

$$L_{90} = \frac{C_{\text{act}}^{m_p} \cdot 10^6 a_p}{\beta \sum_{i=1}^{n} \alpha_i \sum_{k=1}^{m} \gamma_{i_k} \omega_{0_k} \int_0^{P'_{\max}} P'^{m_p}_{i_k} f\left(P'_{i_k}\right) dP'}$$

where

C_{act} was the actual dynamic load capacity of bearing, N;

m_p was the index characterizing load type of bearings of this type;

a_p was the correcting coefficient depending of loading conditions;

β was the loaded mileage proportion;

α_i was the coefficient accounting for distribution of vehicle running using roads of the *i*-th type;

VOL. 13, NO. 10, MAY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

γ_{i_k} was the proportional factor of running on the k-th gear using the i-th type of road pavement;

ω_{0_k} was the bearing loading frequency, cycle/km;

$f(P'_{i_k})$ was the distribution density of reduced load upon running at the k-th gear under the i-th conditions of operation;

P' was the reduced load on the most loaded roller in bearing, N.

For the best confidence of experimental data, the most accurate measurement procedures and instrumentation were selected as well as mathematical statistics for data processing and estimation of accuracy of observation results [15] using PC.

RESULTS AND DISCUSSIONS

The obtained results of preliminary laboratory tests (Table-2) demonstrated that the best antifriction and wear resistant properties were provided by greases containing NSP of Fe, Ni and Zn.

Table-2. Preliminary tri biological tests.

Grease	Moment of friction after stabilization, N·m	Wear, mg
Lithol-24	7.7	3.4
Lithol-24 + Ni	6.1	-0.4
Lithol-24 + Fe	6.8	0.2
Lithol-24 + Zn	6.3	0.3
Lithol-24 + Cu-Sn	6.5	1.0
Lithol-24 + Cu-Pb	6.6	1.8
Lithol-24 + Al-Pb	6.5	1.1
Lithol-24 + Fe-Ni	7.5	0.8
Lithol-24 + Fe-Zn	7.6	-0.4

Composition of the grease containing NSP of metals was optimized during complete factorial experiment. The developed grease named as Cluster-S is protected by Russian patent [16].

The measured moments of friction upon comparative laboratory tests of Lithol-24 and the developed grease are shown by smooth curves (Figure-1). Their analysis demonstrated that maximum moment of friction corresponded to the time of load application, then smooth decrease was observed, and then the moment of friction was stabilized.

Upon testing of Lithol-24 the average moment of friction after stabilization was 7.8 N·m and did not varied in the experiment. The developed grease decreased average moment of friction to 6.6 N·m. Therefore, modification of the commercial grease by NSP of Fe, Ni, Zn resulted in decrease in average moment of friction in simulated tribocoupling by 1.15 times in comparison with basic grease.

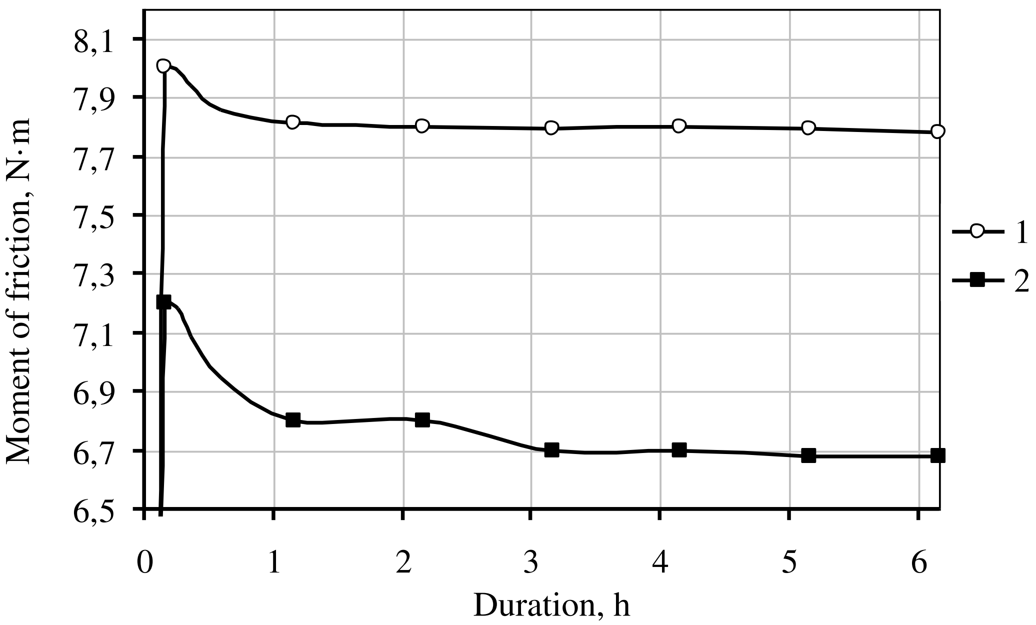

Figure-1. Moment of friction during comparative laboratory experiments: 1 - Lithol-24; 2 - Cluster-S.

Modification of Lithol-24 by NSP of Fe, Ni, Zn improved not only antifriction properties but wear resistance as well. Analysis of the histogram (Figure-2) demonstrated that roller wear in experiments with the basic grease was 5.5 mg. Addition of the proposed NSP composition into the commercial grease decreased the roller wear to 2.4 mg.

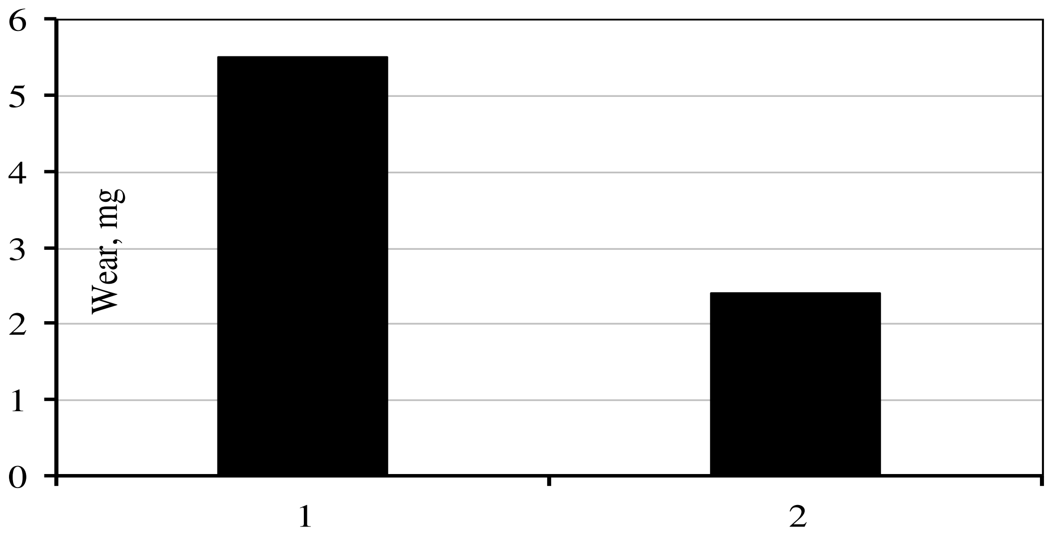

Figure-2. Wear after comparative laboratory experiments: 1 - Lithol-24; 2 - Cluster-S.

Thus, application of the developed grease decreased the wear of simulated tribocoupling by 2.3 times in comparison with Lithol-24.

Taking into account the main reason of failure of roller bearings [17], practical interest is attracted to clarification of the extent of influence of the considered greases on resistance of rolling surfaces against fatigue wear.

This was aided by a series of laboratory experiments. The results in Table-3 demonstrate that the developed grease increases the number of cycles before initial occurrence of pitting by 1.86 times in comparison with Lithol-24. The load causing fatigue flaking increased by 55%.

Table-3. Influence of the considered greases on resistance of rolling surfaces against fatigue wear.

No.	Grease	Number of cycles before breaking, mln. rotations	Maximum load, kN
1	Lithol-24	0.1	1
2	Cluster-S	0.186	1.55

The obtained data can be explained as a consequence of modification of rolling surfaces with the considered nanosized components during friction. The results of comparative tests of antifriction and wear resistant properties of the developed grease demonstrate that the used nanosized additives improve antifriction and wear resistance of surface layers of wearing parts in comparison with Lithol-24. Superior antifriction properties of the modified rolling surfaces promote decrease in tangential stresses upon friction. Both these factors decrease amplitude of microplastic shears in material of contacting surfaces with subsequent higher elastic deformations, lower intensity of oxygen diffusion into surface layer, and this decreases intensity of formation of solid and brittle oxide films [6]. The obtained effect increases the number of loading cycles before initiation of fatigue cracks in surface layer and detachment of weakened material bulk from surface with formation of pitting.

On the basis of data processing according to the procedure in [14], it was determined that the gamma-percentile life of bearings treated by the developed grease in comparison with that using Lithol-24 increased by 2.8 times.

Therefore, the results of commercial tests confirmed high efficiency of the developed grease for improvement of operation lifetime of automotive roller bearings.

CONCLUSIONS

a) Analysis of reliability performances of units and systems of KamAZ vehicles widely used in agriculture industry revealed necessity to increase lifetime of wheel hub roller bearings.

b) Review of methods of improvement of roller bearing lifetime revealed possibility to modify the applied greases by additives. Considering possible components, the main attention was concentrated on nanosized metal powders obtained by laser recondensation.

c) On the basis of preliminary laboratory experiments and complete factorial experiment the optimum grease composition was determined.

d) Comparative laboratory experiments demonstrated that application of the developed grease in comparison with basic Lithol-24 decreased average moment of friction in simulated tribocoupling by 1.15 times, roller wear - by 2.3 times, and increased cycles and load of fatigue flaking by 1.86 and 1.55 times, respectively.

e) Comparative commercial experiments demonstrated that application of the nanocomponent grease increased the gamma-percentile life of wheel hub roller bearings of KamAZ-5320 by 2.8 times in comparison with that using commercial grease Lithol-24.

REFERENCES

[1] Denisov A. S., Baskov V. N., and Grigor`ev S. S. 1980. Issledovanie izmeneniya tekhnicheskogo sostoyaniya osnovnykh agregatov avtomobilei KamAZ v protsesse ekspluatatsii [Study of variation of technical state of KamAZ main units during operation]: Research report. Saratov: Saratov Polytechnic Institute.

[2] Kulakov A. T., Denisov A. S., Makushin A. A. and Baryl`nikova E. P. 2015. Konstruktorsko-tekhnologicheskie metody obespecheniya nadezhnosti avtomobil`nykh podshipnikov po rezul`tatam ekspluatatsii [Engineering methods of safety provision of vehicle bearings on the basis of operation results: Guide book]. Kazan.

[3] Denisov A. S. 1999. Osnovy formirovaniya ekspluatatsionno-remontnogo tsicla avtomobilei [Formation of operation-to-maintenance cycle of vehicles]. Saratov: Saratov Technical University.

[4] Anan`ev S. V. 1999. Povyshenie dolgovechnosti podshipnikovykh uzlov avtotraktornykh transmissii putyom primeneniya protivoiznosnykh dobavok v smazochnye masla [Increasing lifetime of bearings of motor transmissions using wear resistant additives to greasing oils]: Cand. Thesis, St. Petersburg.

[5] Chichinadze A. V. 1994. Prakticheskaya tribologiya (mirovoi opyt) [Practical tribology (global experience]. Moscow: Nauka i tekhnika.

[6] Chichinadze *et al.* A. V. 2003. Trenie, iznos i smazka (tribologiya i tribotekhnika) [Friction, wear

ARPN Journal of Engineering and Applied Sciences

and lubrication (tribology and triboengineering)]. Moscow: Mashinostroenie

[7] Ishchuk Yu. L. 2000. Sovremennoe sostoyanie i perspektivy razvitiya mirovogo rynka smazochnykh materialov [Modern state and challenges of global market of lubricants]. Proceedings, International conference: Development, production and application of lubricants. Berdyansk. pp. 21-22.

[8] Lebedev A. and Ksenofontov I. 2002. Plastika i shariki. Ekspertiza plastichnykh smazok dlya kolyosnykh podshipnikov [Plastics and balls. Analysis of greases for wheel bearings]. Moto, 8.

[9] Fedorchenko I. M. 1979. Sovremennye predstavleniya o mehanizme treniya i iznosa i osnovnye tendentsii v razvitii kompozitsionnykh materialov tribotekhnicheskogo naznacheniya [Current concepts of friction and wear mechanism and main trends in development of greases]. Poroshkovaya metallurgiya. 4, 53-65.

[10] Fedorov *et al*. V. B. 1984. Svoistva materialov s ul`tradispersnoi strukturoi [Properties of materials with ultradisperse structure]. Poverkhnost`. Fizika, himiya, mehanika. 4, 123-130.

[11] Shinkevich E. V., Root L. O. and Il`in A. P. 2013. Poluchenie nitridov titana, tsirkoniya i gafniya pri gorenii v vozdukhe nanoporoshka alyuminiya v smesyakh s dioksidami [Production of titanium, zirconium and hafnium nitrides upon burning in air in mixtures with dioxides]. Inzhiniring georesursov. Izvestiya Tomskogo politekhnicheskogo universiteta. 323(3): 60-65.

[12] Gorohovskii A.V., Safonov V.V., Azarov A.S., Palagin A.I. and Tret`yachenko E.V. 2011. Russian patent 2420459. Potassium titanate powder. No. 2009137938/05; publ. 10.06.2011, Byul. No. 16.

[13] Safonov V. V., Alexanderov V. A., Azarov A. S. and Dobrinskii E. K. 2008. Nanorazmernye dobavki k smazochnym sredam tribosopryazhenii v usloviyakh ikh modelirovaniya [Simulation of nanosized additives to tribocoupling greases]. Remont, vosstanovlenie, modernizatsiya. 2, 8-11.

[14] Lukinskii V. S. and Zaitsev E. I. 1991. Prognozirovanie nadezhnosti avtomobilei [Forecasting vehicle reliability]. Leningrad: Politekhnika.

[15] Semin V. A. and Semina S. M. 2013. Osnovy polucheniya i obrabotki eksperimental`nykh dannykh [Data acquisition and processing: Guidebook]. Tula: TulGU.

[16] Safonov V. V., Kirilin A. V., Dobrinskii E. K., Alexanderov V. A., Safonova S. V. and Builov V. N. 2005. Russian patent 2258080. Grease for heavy loaded friction units. No. 2004104508/04; publ. 10.08.2005, Byul. No. 22.

[17] Perel L. Ya. and Filatov A. A. 1999. Podshipniki kacheniya [Roller bearings: reference book; 2nd edition]. Moscow: Mashinostroenie.