Journal of Polish CIMAC
Gdansk University of Technology
The Faculty of Ocean Engineering and Ship Technology

LUBRICATION OF ROLLING BEARING PAIRS IN ENVIRONMENTAL ASPECT

Michał Styp-Rekowski[1)], Dariusz Ozimina[2]

[1)]University of Technology and Life Sciences
Prof. S. Kaliski Av. 7, 85-789 Bydgoszcz, Poland
tel.: +48 52 3408623, e-mail: msr@utp.edu.pl
[2)]University of Technology
Al.1000-lecia Państwa Polskiego 7, 25-314 Kielce, Poland

Abstract

Lubrication of bearing pairs is the problem often underestimated. Usually it is discussed in aspect of operational features stability of friction pair. In fact, it fulfils much more functions and it should be considered in wider aspect. In this paper environmental problems of rolling bearings lubrication were discussed.

In analyzed environmental aspects of lubrication, the following problems were discussed: interaction of lubricants (also with additives) and rolling bearing elements, influence of a lubricant on surrounding, acting of lubricating medium on bearing elements, interaction of lubricants' components, ecological and environmental functions of bearing's sealing.

Conducted analysis were illustrated by examples taken from authors' own investigations and from literature.

Keywords: *rolling bearing, lubrication, environment, fatigue life*

1. Introduction

Lubrication of the rolling bearing pairs is the problem often underestimated in the stage of design. During operating it is considered the most often in aspect of stability of usable features of pairs. In substance it fulfils many functions, therefore in both mentioned stages (design and operation) of technical object life one should consider it in wide aspect and take a lot of factors into account.

The main goal of presented in this paper investigations was collect information concerning environmental conditionings of lubricating of bearing pairs - especially rolling ones. In carried out analysis the seals, as elements directly connected with lubrication and environment of work, were also considered. Collected information can be helpful in processes of design and operation of machines with rolling kinematic pairs in their structures.

2. Influence of lubricating medium on rolling bearings elements

Basic tasks of lubricants applied in friction's (both: rolling, as well as sliding) kinematic pairs are:

- decreasing friction coefficient value and thereby – decreasing the wear process intensity,
- heat abstraction generated as result of friction work,
- carrying away waste products from friction zone and eliminating them from circulation in

result of filtration,

- corrosion protection of co-operating elements,
- vibration dumping.

Depending on kind, form and amount of lubricants, degree of realization of above mentioned assignments can be different.

Chemical compounds, with atoms of metals or organic functional groups in structure, perform essential function as additions modifying features of lubricants, among others minimizing results of friction process. In lubricating technique alkilotiophosphate, as well as alkilotiocarbamate of metals, as e.g.: zinc (ZnDTP or ZnDTC), antimony (SbDTP or SbDTC) molybdenum (MoDTP or MoDTC) are commonly used. Their presence as lubricant additions favours formation of antiwear superficial layers. Building of this layers occurs under the influence of different forms of energy, accompanying friction processes [6].

Properties and features of formed layers are functions of mutual relations between metal of foundation and atoms of basic metal of grease or addition [2, 8]. During friction process, as the results of these interactions and activation of additions, antiwear layers are generated in the forms – Fig.1:

- metalic (Me),
- inorganic compounds (MeOx)
- macromolecular compounds [-L-L-]n .

The structure of generated layer has one-, two- or three-phase character.

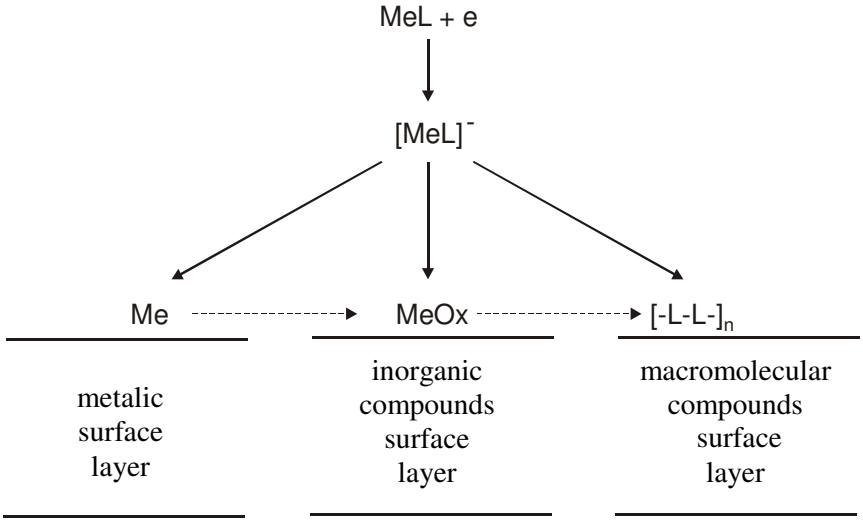

Fig. 1. Generalized mechanisms of changes of tiometalorganic compounds in the process of antiwear surface layers formation [4]

According to different chemical activity of base elements (Me), as well as reactivity of chemical compounds from DTP and DTC groups, antiwear properties of generated layers are diverse. It is affirmed, that they are better for compounds of type MeDTP than for MeDTC. Moreover, all of them in essential degree diminish intensity of wear process - Fig. 2. Conducted experimental investigations were affirmed also, that antiwear layers have reproducible character [4, 5].

Quoted above results of investigations mainly concern conditions of sliding friction. Because slides always accompany to rolling friction, so sliding friction results obtained in presented investigations should indirectly concern phenomena in rolling bearing pairs too. The confirmation of above mentioned assumption may be the fact that in kinematic pairs with non-conformal (concentrated) contact of elements, such asthe rolling bearings, diverse influence of components of

lubricants onto material of foundation was also observed. It was affirmed, that lubricating of molybdenic steel by means of grease with sulphuric addition clearly reduced intensity of wear process in comparison to lubricating without such addition [3]. Different action of grease additions was observed in the case of chromium steels, lubricating by grease with chloric additive. In this materials association enlargement of intensity of wear process was affirmed.

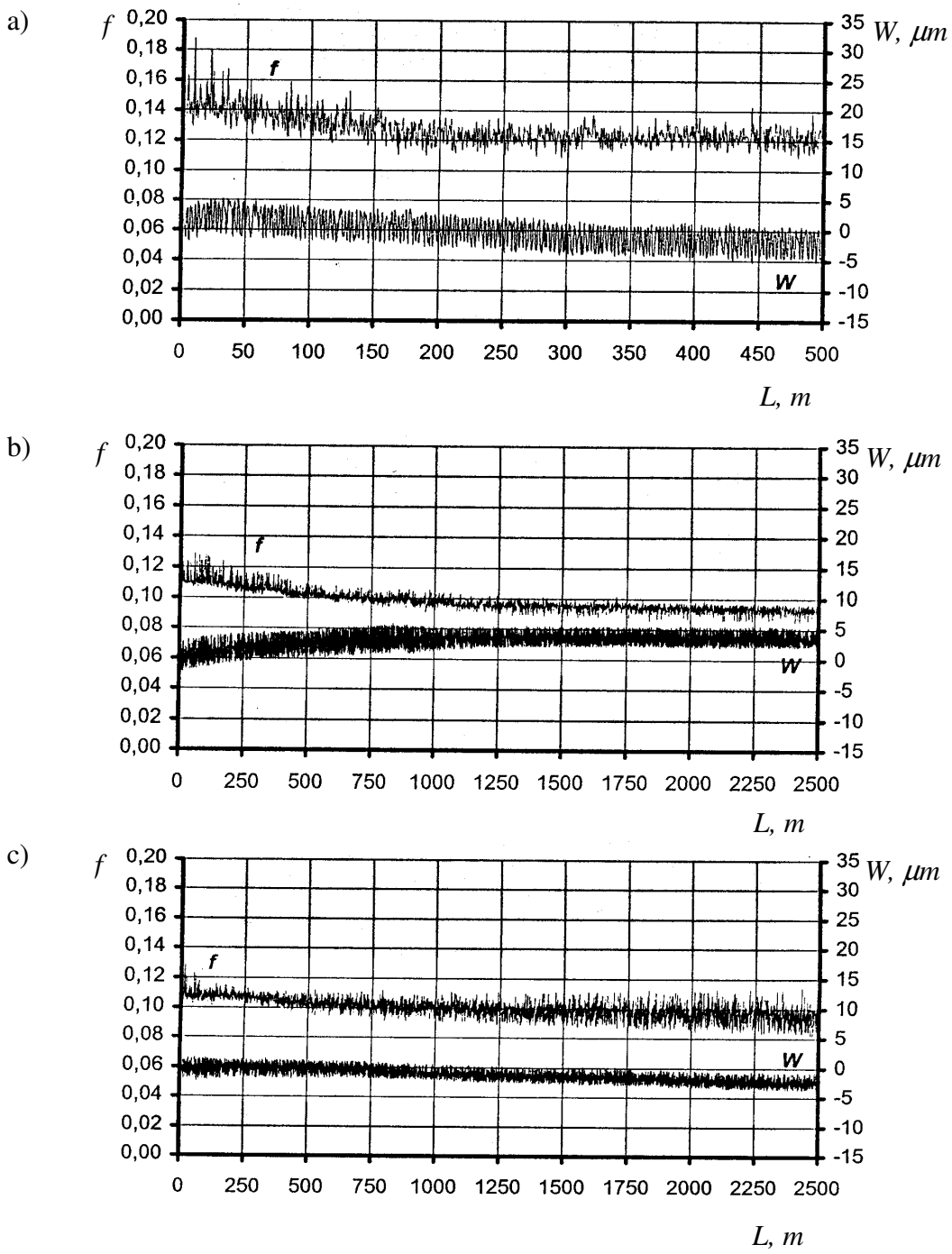

Fig.2. Changes of values of friction coefficient f and linear wear W in function of friction distance L for friction's pair: steel 100Cr6-steel 100Cr6 working in clean paraffin oil (PO) (a), in PO with 1% w/w of AuDTP addition (b) as well as in PO with 1% w/w of ZnDTP addition (c) [4]

The causes of diverse influences of lubricants, as well as their additions onto elements of

bearing pairs are different tribochemical reactions between them and elements or phase components of co-operating parts of kinematic pairs. In first above described case, in result of reaction, layer MoS_2 was created, thereby substance which minimizes friction, in second meanwhile – came into being chemical compound $CrCl_3$, accelerating corrosive processes [9].

3. Influence of lubricating medium on surrounding environment

Influence of lubricating medium on environment in which bearing's pair works, the most often has unfavorable character. First of all it results from chemical constitution of lubricants. As the mixtures of hydrocarbons, produced from rock-oil products (mineral greases) or synthetically, they penetrate into environment and cause its pollution and, in further consequence – its degradation. The actions aiming at minimization of this undesirable phenomenon are two-way:

- limitation of quantity of applied lubricant,
- applying of biodegradable lubricants.

In the first case one use special systems of lubricating, e.g. oil fog or so-called minimum lubricating [7]. In both examples amount of lubricants, potential hazard for environment, is smaller than for traditional lubricating, e.g.: immersion system. Moreover, one should to notice, that decrease of amount of oil simultaneously causes smaller loss of power in rolling bearing – Fig. 3.

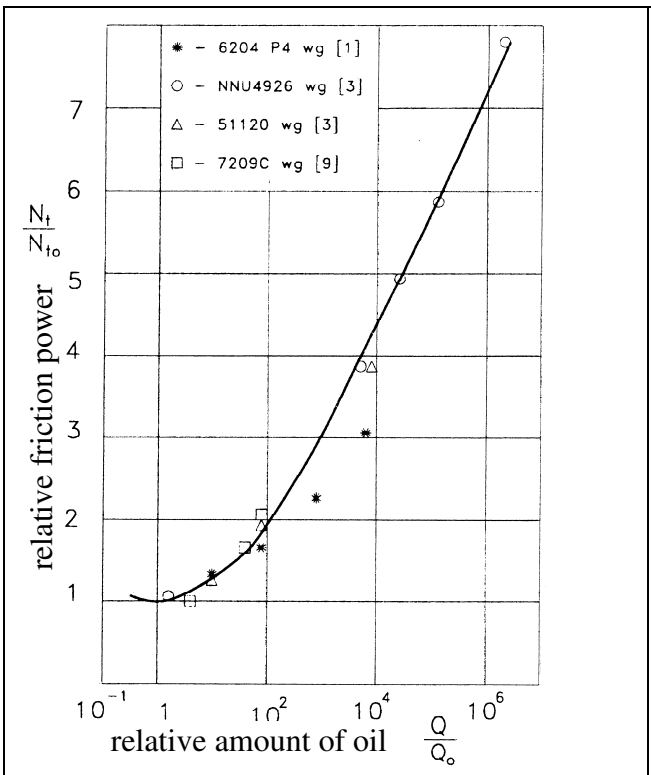

Fig. 3. Changes of friction power N_t in rolling bearings in the function of oil flow Q for different constructional types of rolling bearings (N_{to} – friction power of optimum lubrication, Q_o – optimum amount of oil) [7]

Thus, limiting quantity of lubricants one can observe positive results both, in ecological sphere, as well as – in economic. From investigations, which results are presented on quoted graph appears, that losses of power are diverse and in essential degree they depend on kind of bearing (ball or roller, transverse, angular or axial etc).

Well-known are also the results of investigations showing that resistances of movement in rolling bearings depend on form of lubricant (oil, plastic or solid grease), e.g. [10]. It results directly from different viscosity of lubricants in dependence on their consistence.

Because in practice it is impossible fully eliminate any contact of lubricants with surrounding,

therefore biodegradable lubricants are applied [1]. Under influence of natural environmental factors they have ability to biodegradation onto environmentally harmless components. This feature concerns whole lubricant or some of their fractions; concerns lubricant additives too.

Mentioned above activities minimize the negative influence of lubricants on farther surrounding of machines.

4. Influence of environment on elements of bearing

Thin layer of grease, covering elements of rolling bearing, causes situation that environment of work of bearing pairs has not direct contact with co-operating elements. It has very essential importance if environment is chemically aggressive, e.g. sea surroundings, because it minimizes results of chemical corrosion. It limits also destruction of surface induced by electrochemical corrosion.

In the case of chemically neutral environment, but polluted: including dusts, moisture etc. (e.g. in aggregate or other mineral materials mines), presence of lubricants limits also unfavorable influence of farther environment. It is thanks to fact, that dirt or moisture are chemical or physical bonded with oil or grease, and carried away from zone of friction. This way it causes decreasing intensity of wear process, and the same - increasing durability of rolling bearings.

5. Environmental function of seal

The seal of rolling bearing pair is essential element in assurance of its correct functioning. From surrounding reach the pair uncontrolled streams of energy and matter, which as disturbance of controlled parameters of work, generate answer of tribologic system, not always possible to predicting. Therefore, the basic task of bearing pair seal is to minimize surrounding influence on conditions of pair's work. Among environmental function of seal, the essential are following:

- protection against penetration of dirt from environment to lubricant and further – to contact zone of co-operating elements,
- limitation of possibility of lubricant decrement from contact area of rolling elements with raceways,
- making impossible or considerably impeding access of work's environment of bearing to contact area of bearing's elements.

Realization of above mentioned functions makes possible reaching by pair constructively assumed operational parameters, at expected reliability and durability of machine as the whole. Analysis of mentioned tasks of seal shows its importance in environmental aspect. Moreover, it is possible to notice, that above presented functions refer both: closer (zone of contact of elements of bearing) and farther (surrounding of bearing pair) environment.

Very important and desirable feature of seal is its constancy in time. It assures steady conditions of bearing pair work and thus - operating of machine in stabilized conditions, and the same way – machine long life. Registered and described case of thrust (axial) bearing of joint of bus body in serviceability [9] can be representative example of results of lack or insufficient fulfilling by seal mentioned above environmental assignments.

Fractographic analysis of bearing's elements working surfaces showed presence on them numerous decreases - Fig. 4. Initially it was assumed that their nature was corrosive and it resulted from loss of effectiveness of sealing of bearing's pair. In order to verification this assumption necessary investigations and analyses were realized.

The surface of one of the ball after a few hundred hours of bearing operating is shown in Fig. 5. It has very developed sculpture, with number of tops and cavings in its structure.

On the ground of chemical analyses of applied plastic grease, one shows that presence of grease and its reaction with farther environment was a favourable circumstance of destruction of surfaces of bearing's elements. It was affirmed that it was synthetic grease with silicon densifier.

Spectroscopic analysis of lubricant indicates presence of polar groups type: Cl^-, HPO_4^{2-}, $H_2PO_4^{3-}$, SiO_3^{2-} in its constitution.

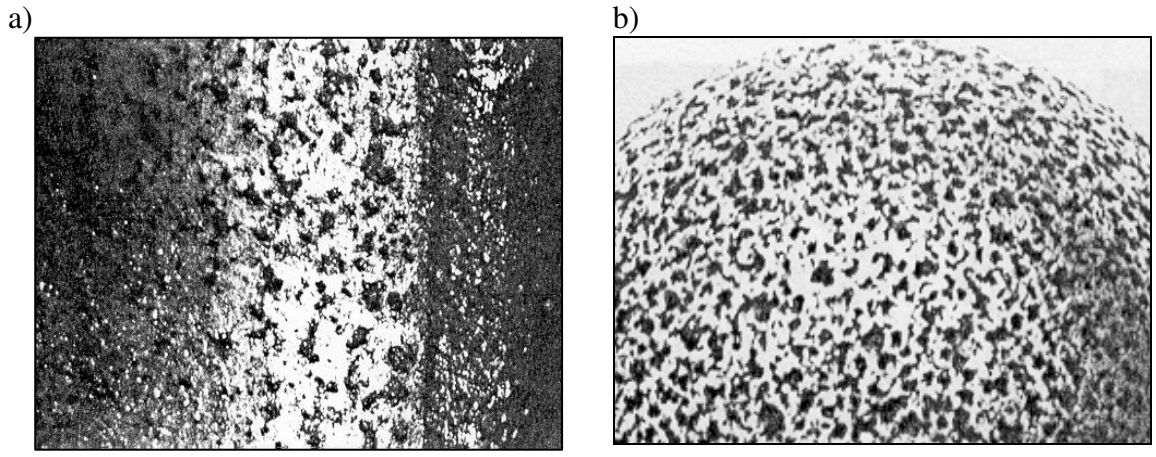

Fig. 4. Macroscopic views of working surfaces of tested bearing with visible characteristic defects on: a) raceway on internal ring, b) ball (mult. 5x)

The surface of one of the ball after a few hundred hours of bearing operating is shown in Fig. 5. It has very developed sculpture, with number of tops and cavings in its structure.

On the ground of chemical analyses of applied plastic grease, one shows that presence of grease and its reaction with farther environment was a favourable circumstance of destruction of surfaces of bearing's elements. It was affirmed that it was synthetic grease with silicon densifier. Spectroscopic analysis of lubricant indicates presence of polar groups type: Cl^-, HPO_4^{2-}, $H_2PO_4^{3-}$, SiO_3^{2-} in its constitution.

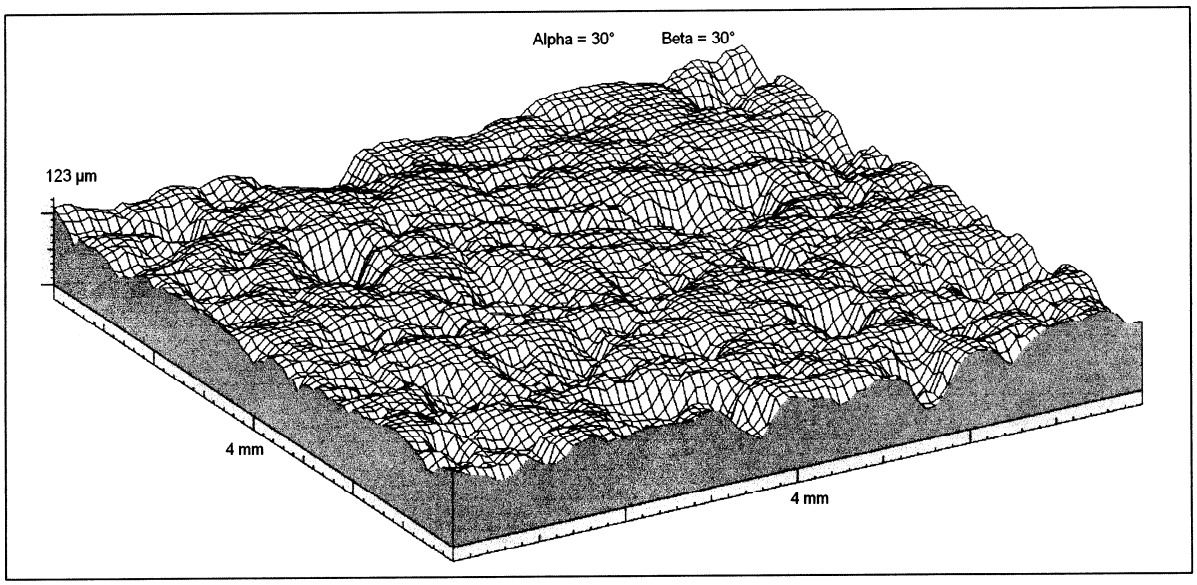

Fig. 5. 3-D view of ball's surface worn out in result of environment acting

Hygroscopic proprieties of lubricant, together with presence of identified polar groups, create

conditions to formation of water solutions of electrolytes in whole volumes of grease or zonal, thus they created environment favourable for electrochemical corrosion.

In conditions of polar water environment (dipolar moment of water particle $\mu_{H_2O} = 1{,}84D$) polar groups have tendencies to migration according to locally created electromotive strengths. Presence of this energy, follows from formation of punctual residual currents, generated in consequence of potentials' differences resulting from appearing of oxygenate forms of iron as products of reactions :

$$Fe + nH_2O \rightarrow FeO + 2nH^+ + ne \quad (1)$$

or

$$Fe + mH_2O \rightarrow Fe_2O_3 + 2mH^+ + 3me \quad (2)$$

Then, redox type half-cells arise, e.g. from reactions:

$$Fe \rightarrow Fe^{2+} + 2e \quad (3a)$$

or

$$Fe \rightarrow Fe^{3+} + 3e \quad (3b)$$

in forms $Fe(II) \,|\, Fe(III) \cdot aq$, or from reaction:

$$Fe(OH)_2 \Leftrightarrow HFeO_2^- + H^+ \quad (4)$$

in forms: $Fe(II) \,|\, HFeO_2^- \cdot aq$ or $HFeO_2^- \,|\, Fe(III) \cdot aq$.

Moreover, essential importance have reactions with participation of molecular oxygen, leading to creation of alkaline environment:

$$O_2 + 2H_2O + 4e \Leftrightarrow 4OH^- \quad (5)$$

increasing susceptibility to pinhole corrosion of metal surface.

The components of identified in grease polar groups probably originate from environment of work and they become impurities of grease. Metals such as: lead, copper, zinc, nickel, manganese, are presented in dusts generated during processes of thermal destruction of solid fuels, as well as solid and semi-liquid waste substance. They carry danger of migration of heavy metals to superficial zone of surface layer including water and this way - create conditions to formation of electrolytic cells of metallic type.

In result of chemical analysis it was confirmed that in conditions of ineffective seal and resulting pollution of closer environment of work, as well as its humidity (tested journal bearing of bus bodies joint worked in such conditions), presence of grease inside the bearing created additional, favorable conditions to occure of pinhole corrosion.

Measurements of geometrical structure of balls and bearing raceways surfaces – see Fig. 5, confirmed corrosive genesis of decrements in working surfaces. In the measurements extended TalyMap Expert programme of measuring machine Talyscan 150 was used [9]. The results of this investigations were taken down in Table 1. Together with results of microscopic investigations, as well as chemical analysis, they practically exclude fatigue character of material destruction.

Table 1. The values of some parameters of decrements on surfaces of balls and raceways of rolling thrust bearings

Item	Decrement's parameters	Units	Values of dimensions	
			ball	raceways
1	area	μm^2	446.000	149.000
2	volume	μm^3	12.800.000	3.558.215
3	maximum depth	μm	71,6	59,1
4	average depth	μm	28,7	23,9

Moreover, environmental function of seal consists in limitation above mentioned penetration of pollutions to friction zone. It favors formation of conditions of proper mutual co-operation of elements of rolling pair, because chemical and mechanical cleanness of contact area of co-operating elements is the diminishing factor of intensity of wear processes.

6. Recapitulation

Carried out theoretical analysis, supported by experimental investigations, showed clearly great importance of environmental factors for proper work of rolling bearing pairs. Regarding most of them is indispensable already in stage of design and construction of machine because they usually determine its usable features. The activities in this stage also make independent functioning of machine, its efficiency and reliability from farther environment.

Assurance of possible low noxiousness of machine for environment is essential problem too. In this regard significant function fulfils seal of machine's pairs. Correctly designed and made it protects farther environment against pollution by applied in machine lubricant.

REFERENCES

[1] Battersby N.S.: The CONCAWE Biodegradability Test for Oil Products. Proceedings of the 12th International Colloquium Tribology 2000 - Plus. Esslingen (Germany) 200, pp. 113-116.

[2] Bergman F., Gudmand-Hřyer L., Eriksson M., Jacobson S.: The Effect of Cu_2S, PbS, Sb_2S Solid Lubricants on the Occurance of Brake Squeals for Three Automotive Brake Pad Matrix Types. Proceedings of *8th International Conference on Tribology NORDTRIB '98*. Ebeltoft – Aarhus (Denmark) 1998, pp. 665-672.

[3] Łubiński T., Druet K.: Laboratory Investigation of Phenomenology of Rolling Elements Surface Layer Fatigue. Scientific Books of Rzeszów Technical University 82, serie Mechanics No. 28. Rzeszów 1991, pp. 447-454 (in Polish).

[4] Ozimina D.: Antiwear Layers in Tribological Systems. Kielce Technical University Publishers, serie Monographs No. 33, Kielce 2002 (in Polish).

[5] Ozimina D.: Tribological Properties of Antifriction Layers Formed under the Effect of Selected Gold Compounds. Tribologia No. 5-6/1997, pp. 807-817 (in Polish).

[6] Ozimina D., Styp-Rekowski M.: Evaluation of ZnDTP Tribochemical Reactivity by Means of Electrochemical Simulation. Proceedings of *8th International Conference on Tribology NORDTRIB '98*. Ebeltoft – Aarhus (Denmark) 1998, pp. 121-130.

[7] Potrykus J.: Energy Saving Lubrication of High Speed Rolling Bearings. Proceedings of Conference „*Progress in development of bearings rolling – ISKRA 100*". Kielce Technical University Publishers, Kielce 1996, pp. 251-264 (in Polish).

[8] Pytko S.: New Greases and Oils and Their Influence on Friction Processes. Scientific Books of Rzeszów Technical University 36, serie Mechanics No. 15. Rzeszów 1987, p. 221-230 (in Polish).
[9] Styp-Rekowski M.: Meaning of Lubrication in Operation Process of Rolling Pair. Tribologia No. 5/2003, pp. 329-340 (in Polish).
[10]Styp-Rekowski M.: Significance of Constructional Features for Angular Ball Bearings Life. Technical and Agricultural University Publishers, serie Monographs No. 103. Bydgoszcz 2001 (in Polish).