THE QUALITY OF MATERIALS APPLIED FOR SLEWING BEARING RACEWAY – TECHNICAL PAPER

Marek Krynke[1,*], Jacek Selejdak[1], Stanislaw Borkowski[1]

[1]Czestochowa University of Technology, Faculty of Management, Institute of Production Engineering, Aleja Armii Krajowej 19B, 42-200 Częstochowa, Poland

[*]corresponding author: e-mail: krynke@zim.pcz.pl

Resume

Selected slewing bearings and their application have been described in this article. Basic causes of the damage pitch surfaces of slewing bearings have been analyzed and examples of the damage have been presented as well. Special attention was paid to these kinds of damage which appeared most often in the case of the pitch surfaces of the bearings and those ones which very often cause premature exchange of the bearing and its scrapping. On the basis of the conducted studies it was stated that the main cause of the damage to the pitch surfaces of the bearings is the excessive load of rolling elements. Based on the results of the conducted analysis, actions limiting the occurrence of the damage to the pitch surfaces of the bearings, which lead to their premature exchange, have been proposed. One of the suggested actions, limiting the premature exchange of bearings, is the necessity of exceptionally thorough design and selection of the slewing bearings, including the conditions of their foundation.

Available online: http://fstroj.uniza.sk/journal-mi/PDF/2012/21-2012.pdf

Article info

Article history:
Received 10 May 2012
Accepted 2 July 2012
Online 8 October 2012

Keywords:
Slewing bearings;
Application;
Damage;
Pitch surface of slewing bearings

ISSN 1335-0803 (print version)
ISSN 1338-6174 (online version)

1. Introduction

Slewing bearings constitute a specific group of bearings used in mechanical engineering. Basic features which distinguish them from other types of bearings are: large values of pitch diameters dt (reaching several meters), a different system of mounting their rings to supporting structures (mostly by means of clamping screws placed on the perimeters of rings), static nature of work (they work as slow-speed at the rotational speed which does not exceed several revolutions per minute), specificity of the load (high Q values of axial forces, radial forces H and specified tilting moment M attached to the head), a large number of rolling elements (reaching even several hundred) [1]. Hence for slewing bearings rather are not in force in their exploitation the same criteria in the assessment of the state of wear like for normal bearings. Therefore, it was introduced, as important functional feature the concept: service life of slewing bearing raceway.

The selection of the slewing bearings, especially in the initial phase of designing, is conducted on the basis of the characteristics of the static capacity, presented in catalogues as the correlation of the transferred tilting moment M and the axial force Q for the assumed values of the radial force H. Determining the characteristics, which specify the usefulness of the bearing, is therefore one of the most important stages of design. The static capacity, conditioned by the maximum and acceptable pressure in the contact zone of the most loaded rolling element, is mainly calculated for a slewing bearing [2]. Fig. 1 presents the load of a slewing bearing.

Working parameters of the machine, such as load, speeds, the temperature, the precision of the work and operation requirements, are needed for choosing the most appropriate type and size of the bearing. Expected analytical life for every bearing is calculated on the basis of eight assumptions [18]:

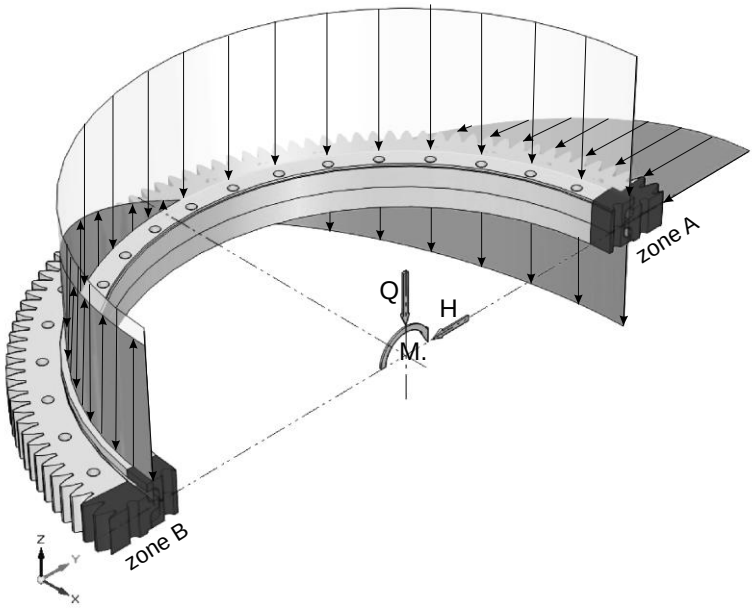


Fig. 1. The load of a slewing bearing

- the bearing has a high quality and there are not any manufacturing defects,
- in a given application there is appropriate bearing,
- dimensions of leaf sub-assemblies with the bearing are correct,
- the bearing is installed correctly,
- appropriate lubricating medium, in the appropriate amount, is on time delivered to bearing,
- the bearing node is secured in the right way (bearing seal),
- bearing system is fitted into working conditions,
- an appropriate maintenance service is completed.

If all these conditions will be fulfilled, the bearing should achieve its analytical life. Unfortunately, it is possible rather hypothetically. Often, there are circumstances which are making impossible to obtain „perfect" working conditions. Common error made through users is following assumption: if the bearing is perishable, it could mean that the bearing capacity was not sufficient. Expensive modernizations in order to increase the bearing capacity are realized, but premature break-downs are appeared again.

2. Application and examples of slewing bearings

Large-size slewing bearings are used mainly in mechanisms of revolutions of mills e.g. in excavators, handling cranes, building cranes, mobile cranes, geological drills and in radar antennae etc. [3], what has been presented in Fig. 2.

The analysed bearings can obtain highly loaded stiff BEARINGS (łożyskowań) which require a small space at a relatively large diameter of the opening. Taking into consideration the specific nature of the slewing bearings' work, that is slow revolving or oscillatory movements, these bearings are mainly calculated on the static capacity, which is conditioned by the maximum and acceptable tension in the contact zone of the most loaded rolling element [2, 3, 5 – 7, 19]. Examples of the slewing bearings have been shown in Fig. 3.

Slewing bearings, like all rolling bearings take wear, resulting from the connection between the rolling elements and the race of the bearing. Such wear, in which the bearing is destroyed after working for a definite number of hours, that is reaching planned durability [8], is called the natural wear in literature [9].

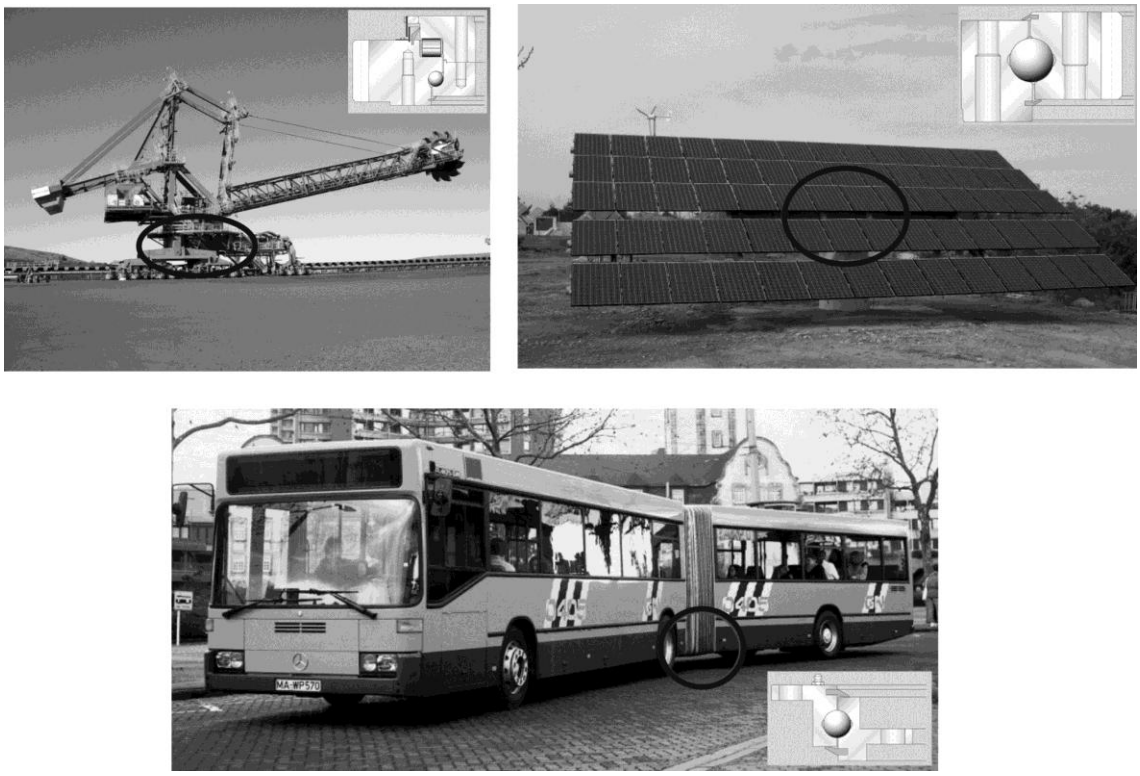
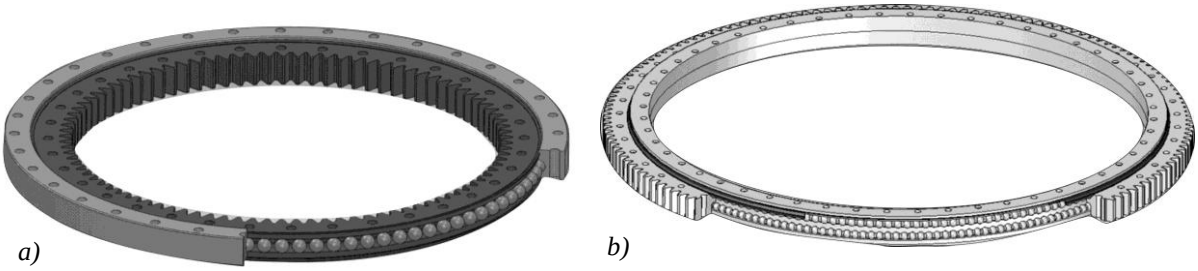


Fig. 2. The examples of applying slewing bearings [4]



a) *b)*

Fig. 3. The examples of the slewing bearings: a) single-row ball bearing with internal mesh, b) double-row ball bearing with external mesh

Slewing bearings work in uncomparably harder conditions than conventional bearings usually do, in view of heavy loads of the rolling elements, plastic deformation of the races, uneven distribution of load on the perimeter of the bearing and difficulties with retaining optimum conditions of lubrication. High cost connected with the replacement of the bearing and high cost of the bearing itself must be taken into account as well. Therefore, they are rather not obligatory in their exploitation, especially in the case of bearings of large sizes, cryteria useful in evaluation of the condition of wear for a regular bearing [5]. The wear of the slewing bearings is allowed considerably beyond the criteria, e.g. for bearings with non-hardenable races large amount of rolling out is allowed, which in some periods of exploitation is even beneficial [3].

Thus, as the presented issues show, apart from natural wear there is also an array of examples of standard wear only for the slewing bearings on functioning, which has a significant influence also on quality [11 ÷ 14] of the pitch surface.

3. Analysis of the damage to the race of slewing bearings

During the work of a bearing, cyclical load of the race takes place as a result of reboring the rolling elements. By virtue of a very small rotational speed of the slewing bearings, gradual wear of the race takes place (mostly because of spalling) or chipping connected with pitting happening occasionally [15]. Pitting in the slewing bearings emerges as a result of natural wear caused especially by large loads of the rolling elements, what has been shown in Fig. 4.

Slewing bearings, whose races are being hardened to the surface, show smaller usable durability. As a result, the bearing has to be replaced as soon as the first signs of pitting occur. It does not result from typical spalling (which by reason of slow speed of the slewing bearings is of minor significance), but from fastest-spreading large spalling of the hardened layer on long stretches of races. It leads to the necessity of withdrawing the bearing from exploitation, otherwise rolling elements may be jammed and consequently, the bearing is destroyed, and in extreme cases it may cause the crack of the rings. The damage of the race on large surfaces are shown in Fig. 5.

The main cause of the phenomena presented in Fig. 5 is overloading of the rolling elements. It can be brought about by the excessive external load during the exploitation of a machine. It can also result from excessive slackness in the bearing, what reduces the number of rolling elements which take place in moving the load, and what causes the increase

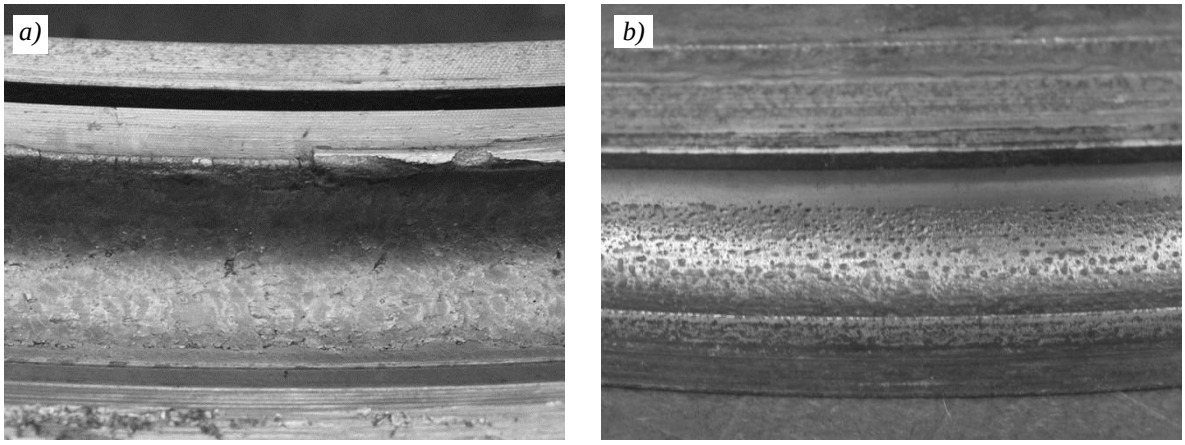


Fig. 4. The traces of pitting on the race of a ball bearing: a) double-row, b) single-row

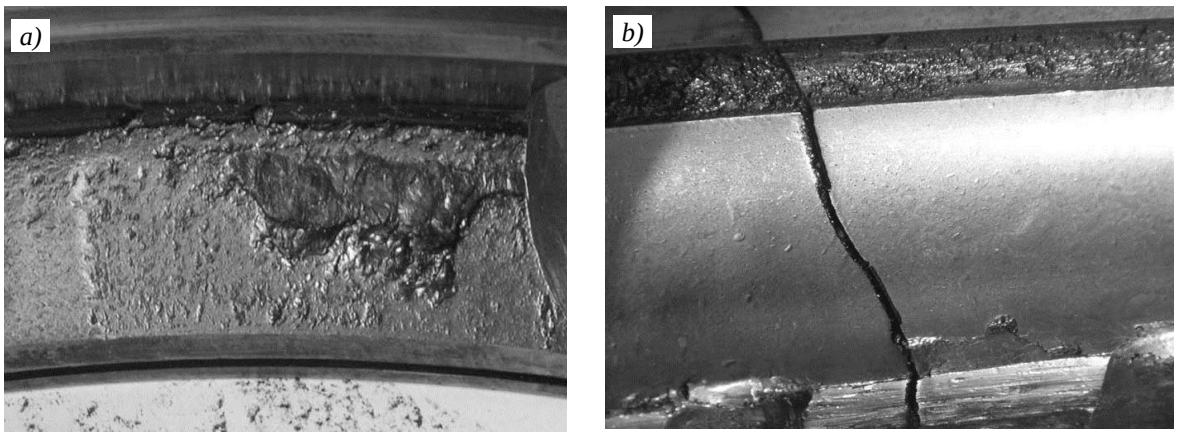


Fig. 5. The damage to large fragments of the race of a slewing bearing: a) spalling of the hardened layer, b) crack in the ring of the bearing

in forces which load some of the rolling elements. The frequent cause of such damage to the bearing is its foundation on the supporting structures which are too liable. As a result of their uneven deformation, so-called 'hard points'arise on the perimeter of the race. In this situation, acceptable load can be considerably surpassed. Another cause of the race damage can be too small thickness of the hardened layer. The thickness of this layer should be selected on the basis of a required value of contact stresses on the race of the slewing bearing [2]. The contact stresses can be found where a ball or a roller meets with the bearing race, at the same time the largest effort of the substances in contact is not on their surface but on some depth inside the material, in the so-called Bielajew point [1, 16]. Hence, the thickness of the hardened race should be properly selected, that is it should be bigger than the thickness of the position of the Bielajew point so that the yield point of the material core is not crossed and not plasticized.

The sort of fatique wear is partly connected with the conditions of lubrication of the bearing. In the case of poor lubrication conditions, which can take place in some devices, before pitting occurs, spalling of the surface can appear and it would then lead to premature wear because the estimated durability is usually connected with the criteria when pitting occurs. Additionally, in the case of inappropriate lubrication, the races of the bearings are not protected from corrosion, corrosive wear is premature and corrosive damage of the races is a place of initiation of the accelerated fatique wear. The example of the corrosive wear has been presented in Fig. 6.

A basic lubricating medium in the slewing bearings is plastic grease. There are two structural solutions distinguished. They are connected with leading the grease to the bearing: through the openings which are directly produced in the rings of the bearings, where the greasers are fixed (this method is used more),and by means of supply conduits, which supply the grease from the greasers fixed outside the bearing. The greasers, mounted to the rings of the bearing, usually require hand operation, but at present using automatic grease batchers are more recommended, especially in continuous running and semi-continuous devices. Bearings which are not lubricated can be only applied in places where their destiny requires it, e.g. in food industry or medical appliances. In this case, when a bearing is chosen, the load of the rolling elements cannot cause plastic deformations in the zone of the largest effort under the surface race (in the Bielajew point). Therefore, the main cause of the quick pitting is avoided. In practice, it means that the bearings work below their catalogue load capacity.

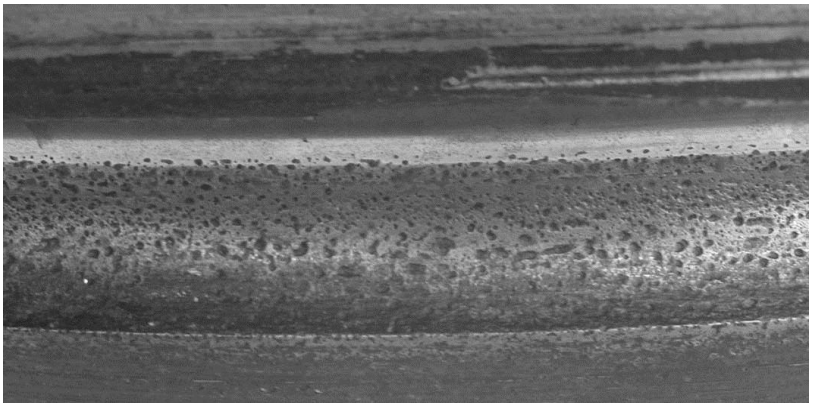


Fig. 6. The traces of both corrosion and pitting on the race of a ball bearing

4. Conclusions

The conducted analysis shows that one of the main factors deciding on the appropriate work of the slewing bearing is making sure that the axial play in the bearing is appropriate. It refers especially to the slewing bearings in which the rollers are the rolling elements. In the case of the bearings with a hardened pitch surface, the cause of the damage to the races can be errors in heat treatment (micro-cracks), but they take place very seldom in view of the thorough control of the hardened layer in the case of the producers of the bearings. The defects of this kind happen more often in critical points resulting from technology [17] (narrow, not hardened zone) or from the structures of the bearings (openings for filling the bearings with not separated rings). The discussed forms of the wear of slewing bearings are different from typical forms of the wear of common bearings. The main cause of their wear is most often the excessive load of the rolling elements, brought about by:

- bearing slackness which increases during the process of exploitation and as a consequence, reduces the active number of the rolling elements,
- large and uneven flexibility of supporting structures and susceptibility for bending and torsion of bearing rings what leads to a considerable exceeding of the predictable load of the rolling elements in the so-called hard points on the perimeter of the bearing,
- exceeding the external load during the work of a bearing.

On the basis of the conducted research, it has been shown that exceptionally thorough design and selection of the slewing bearings are necessary, and at the same time their foundation has to be taken into consideration. The angles of aperture of the race profile must be precisely determined in ball bearings. The selection of the bearings only on the basis of catalogue capacity can be in many cases insufficient. In order to avoid the degradation of the edges of the race in justified cases, a bigger bearing should be chosen than it can result from the analysis of the catalogue capacity. It particularly refers to the ball bearings with wire races in which the angle of the race aperture is rather small.

The discussed causes of the wear of the slewing bearings do not include all cases, especially the design problems and problems with exploitation of large slewing bearings of not hardened races.

References

[1] L. Kania: Analiza obciążenia wewnętrznego łożysk tocznych wieńcowych w aspekcie ich nośności statycznej *(Analysis of internal load of slewing bearings in respect of their load carrying capa city)*, Wyd. Politechniki Częstochowskiej, Częstochowa, 2005 *(in Polish)*.

[2] E. Mazanek: Zagadnienia konstrukcyjne i wytrzymałościowe w wielkogabarytowych łożyskach tocznych wieńcowych *(Constructional and strength problems of large-size rolling bearings)*, Wyd. Politechniki Częstochowskiej, Częstochowa 2005 *(in Polish)*.

[3] T. Smolnicki: Fizykalne aspekty koherencji wielkogabarytowych łożysk tocznych i odkształcalnych konstrukcji wsporczych *(Physical aspects of coherence of large-size rolling bearings and deformable support structures)*, Oficyna Wyd. Politechniki Wrocławskiej, Wrocław 2002 *(in Polish)*.

[4] http://www.rotheerde.com/GB/anwendungen_gwl.shtm (17.04.2012)

[5] T. Gibczyńska, S. Pytko: Łożyska toczne wieńcowe *(Slewing berings)*, AGH, Kraków 1999 *(in Polish)*.

[6] J. I. Amasorrain, X. Sagartzazu, J. Damián: Mechanism & Machine Theory 38(2003) 479-496

[7] T. Smolnicki: Przegląd Mechaniczny 58(1999) 16-20.

[8] T. Gibczyńska: Zagadnienia Eksploatacji Maszyn 24(2) (1999) 249-263.

[9] H. Krzemiński-Freda: Łożyska toczne (*Rolling bearings*), PWN, Warszawa 1989 *(in Polish)*.

[10] S. Borkowski: Mierzenie poziomu jakości *(Measurement of quality level)*, Wyd. Wyższej Szkoły Zarządzania i Marketingu w Sosnowcu, Sosnowiec 2004 *(in Polish)*.

[11] P. Ptak, R. Ulewicz: In: Proc. Semdok 2007 - 12th Int. of PhD. students' seminar. Ed.: A. Töroková, ŽU Žilina 2007, pp. 41-43.

[12] R. Ulewicz , F. Novy, M. Mazur: In.: Quality Product Improvement, Eds.: S. Borkowski, R. Ulewicz, TRIPSOFT Trnava 2011, pp. 55-66.

[13] R. Stasiak-Betlejewska, M. Jagusiak, K. Knop: In.: Conditions of Machines Operating and Quality Products, Eds.: S. Borkowski, J. Selejdak, Liga-Press Lviv 2011, pp. 21-32.

[14] J. Selejdak, A. Czajkowska: In.: Quality Materials Improvement 2007, EDIS Żilina 2007, pp. 100-105.

[15] M. Hebda, A. Wachal: Trybologia *(Tribology)*, WNT, Warszawa 1980 *(in Polish)*.

[16] J. Brändlein, P. Eschmann, L.Hasbergen, K. Weigand: Ball and Roller Bearings: Theory, Design and Application, 3rd edition, John Willey, 1999.

[17] E. Mazanek: Modele obliczeniowe i charakterystyki nośności statycznej łożysk tocznych wieńcowych *(Calculation models and characteristics of the load carrying capacity of slewing bearings)*, Wyd. Politechniki Częstochowskiej, Częstochowa 1999 *(in Polish)*.

[18] SKF Polska S. A.: Przegląd Mechaniczny 70 (10) (2011) 3-6.

[19] M. Krynke, L. Kania, E. Mazanek: Key Eng. Mater. 490 (2012) 166-178.