6th INTERNATIONALMULTIDISCIPLINARY CONFERENCE

ANGULAR CONTACT BALL BEARINGS PASSED BY ELECTRIC CURRENT

Racocea Cristina, Racocea Cezar, Nacu Ionuț
Technical University "Gh. Asachi" of Iasi

Abstract. *The paper presents the experimental results obtained on two test rigs. The rigs are meant to investigate the phenomena connected to the passing of electric current through bearings. The research conducted under direct current on both test rigs have given evidence to the existence of a breaking through voltage of the lubricant film, after which the electric current intensity shows a tendency to continuously increase, even if the voltage remains constant or is decreasing.*
The first tests conducted on the rig with two bearings under alternating current indicate a similar behavior of the bearings when they are subjected to an increasing alternating or direct current voltage.

Key words: *Bearing fatigue life; Electric current; Experimental results.*

1. INTRODUCTION

In the paper "Angular Contact Ball Bearings – A Possible Way for Electrical Currents in Machinery Specific Test Rigs" were presented two test rigs created for the study of the passing of electric current through bearings. The rigs have been designed considering that the bearings under test are components of an electric circuit, they rotate at an imposed number of revolutions and are subjected to a given radial load. The electric current voltage, the rotating speed and the load on the bearing can be controlled within a wide range of values.
The first rig ,designed and built by the authors, is intended to test radial ball bearings The switching on of the electric current which passes through the tested bearing during its operation is achieved by means of a collecting brush(fig.1). It was found that the switching on of the electric current that passes through the bearing by means of the collecting brush is an

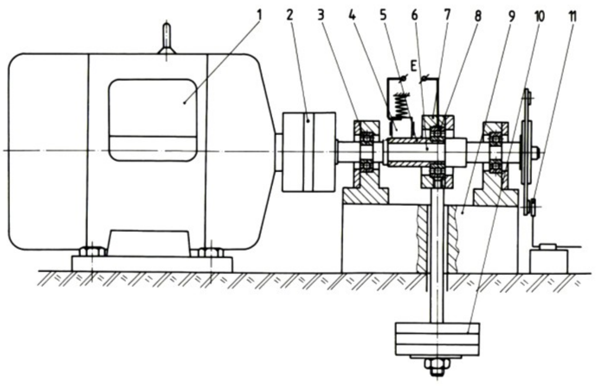


Fig.1 *Rig with a single tested bearing*

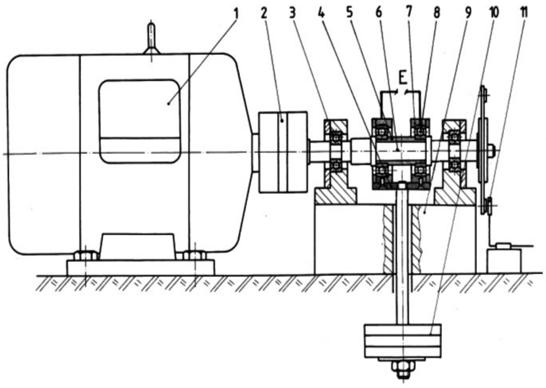


Fig.2 *Rig with two bearings under test.*

impediment, as the electric resistance of the collecting brush is of the same order of magnitude with the electric resistance of the bearing. On the other hand, between the collecting brush and the bronze bushing there occurs a sliding friction which is totally different from the rolling friction that develops in the bearing during operation. For this reason, the presence of the collecting bush generates important errors, especially in testing the bearings under alternating current.
The second rig removes the drawbacks found in the former one. Instead of the collecting brush, another bearing, identical to the former one, was placed there. In this way two electric serially connected roller bearings are tested.

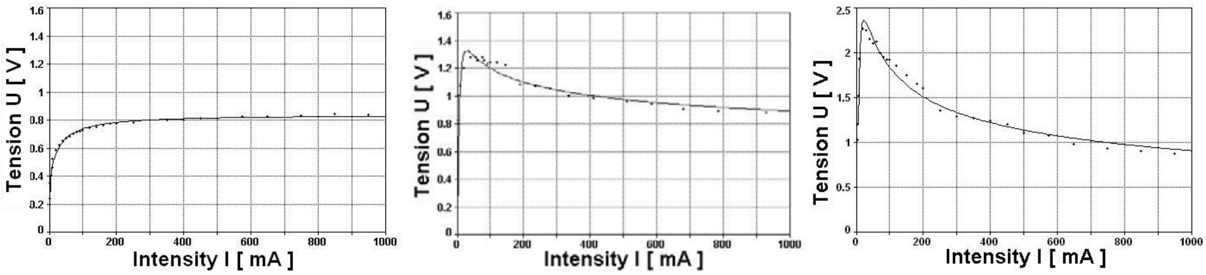
2. Experimental tests conducted on the one-bearing test rig

The experimental tests were carried out on a 6203 2RS bearing which is currently manufactured by KOYO Romania S.A. from Alexandria . This is a general use bearing which is part of the electric low power rotating machinery, e.g. automobile alternators.
Three types of lubricants were used during test time: ALVANIA R2, BEACON 325 and silicone grease. In terms of electric current passing through bearings, the main characteristic of the lubricating films used is their electric resistivity. A terra-ohmmeter E6-13A was used to measure it, and the results were the following:

- lubricating film BEACON 325: $\rho_{volum} = 9.15 \cdot 10^7 \Omega \cdot m$
- lubricating film ALVANIA R2: $\rho_{volum} = 2.12 \cdot 10^9 \Omega \cdot m$
- silicone grease: $\rho_{volum} = 2.0 \cdot 10^{11} \Omega m$

Another important element which influences decisively the passing of the current through bearings is the thickness of the lubricating film between the bearing races and the rolling balls during operation. In the case of a punctual contact between the bearing races and the rolling balls, as is the situation with the 6203 2RS bearing, determining the thickness of the lubricating film is a complex issue which supposes solving a system of equations in which intervene: Reynolds' equation of lubricant flow by two directions, the equation of elastic deformations in the contact and vicinity area, the equations of lubricant viscosity and density variations with pressure and temperature, and the equation of the energy balance and the finding of temperature distribution in the lubricating film, depending on the frictions within the film.
The most widely used solutions for these equations system are those obtained by Dawson and Hamrook in determining the minimum and central thicknesses of the lubricating film in a punctual contact, under isothermal conditions. The estimation of the lubricating system in the points of contact between the bearing races and the rolling balls is achieved using the lubricating parameters λ in the point of contact of the ball with the two rings, the interior and the exterior one. In order to show the differences which occur when the electric current passes through various types of lubricant, the test at a revolution *n = 1200 rev/min* and a radial load *Fr = 15 N* was considered significant.
In this situation, the lubricating parameter λ in the point where the ball makes contact with both rings is $\lambda > 3$, which ensures an entirely hydro-dynamic lubrication.
The bearing under test was lubricated, in turn, with BEACON 325, ALVANIA R2 and silicone grease. The tests were done after about an hour from turning on the rig, when the thermal regime of the bearing operation had been stabilized, by applying on the bearing a continuous voltage from a battery. The applied voltage value modification was made by means of a potentiometer, while the voltage and the intensity were measured using a

voltmeter and an ammeter, respectively. Fig.3 shows the way in which the voltage applied on the tested bearing depended on the electric current intensity $U(I)$.



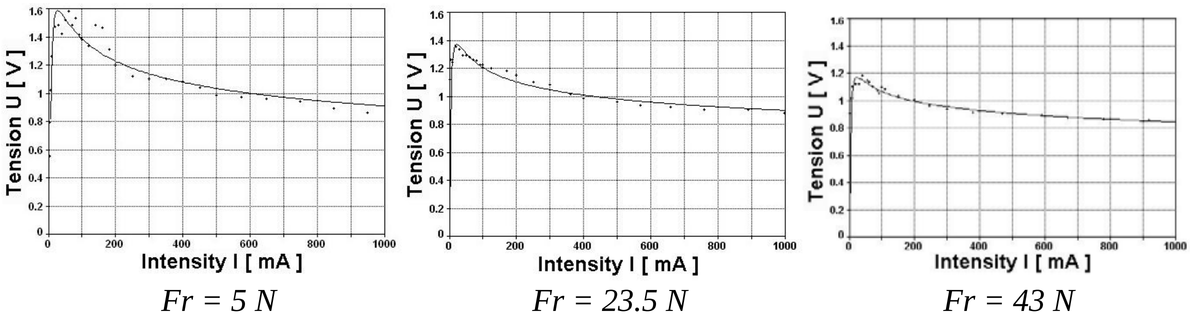
BEACON 325 grease *ALVANIA R2 grease* *Silicone grease*

Fig.3 *Lubricating films of various resistivities.*

In all these cases we saw that, at low voltage, the intensity of the current passing through the tested bearing is low, but, after the film was broken through, it increases , even if the voltage applied on the two rings of the bearing remains constant, or decreases. This phenomenon may be explained by the ionizing of the lubricant in the balls and bearing races contact area. At the same time, the magnitude of the breakthrough voltage of the lubricant is higher when the lubricants have a higher resistively.

All three types of lubricant were tested on that occasion: BEACON 325, ALVANIA R2 and the silicone Vaseline, while modifying the radial load and the testing revolutions. As ALVANIA R2 is mostly used in lubricating radial ball bearings, it was considered to be a representative one.

In order to show the influence of the radial load on the electric current passing through, the 6203 2RS bearing was consistently lubricated with ALVANIA R2, was subjected to a rotational speed of *1200rev/min.*, which ensures a hydro-dynamic lubrication of the bearing, and was tested, successively, at 5 radial loads, of *5N, 15N, 23.5N, 34N,* and *43N*. The voltage dependence on the electric current intensity when the loads of *5N, 23.5N,* and *43N* were applied, are presented in Fig.4.



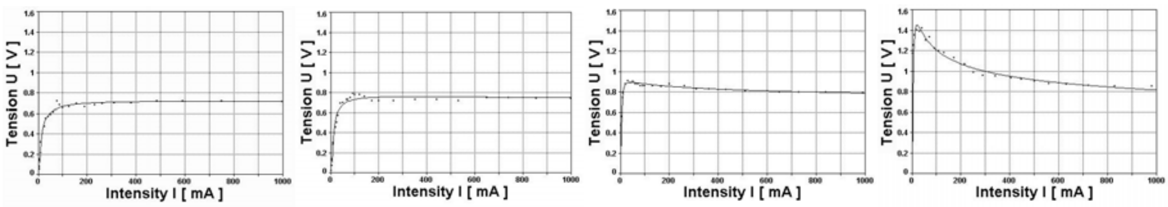
Fr = 5 N *Fr = 23.5 N* *Fr = 43 N*

Fig.4 *The influence of radial testing load.*

Analyzing these diagrams, we can see that the lubricant breakthrough voltage tends to decrease from *1,6 V(cc)*, for the radial load *Fr = 5 N*, to a voltage of *1,18 V(cc)* for a radial load of *Fr = 43 N*. This fact is explainable as the thickness of the lubricating film decreases as well, from $0.265\mu m$ to $0.227\mu m$ in the point of contact between the ball and the interior ring, and from $0.235\mu m$ to $0.278\mu m$ in the point of contact between the ball and the exterior ring.

The most interesting results are those which show the dependencies created when the electric current passes through the bearing at various testing speeds. To this purpose, we tested the

same type of bearing, 6203 2RS, when lubricating it with ALVANIA R2, and loading it by a radial force *Fr = 15 N* at various speeds ranging between *n = 100 rev/min* and $n = 1600 rev/\min$. These tests sweep all the lubrifying regimes, starting with the limit lubrication at the speed of $n = 100 rev/\min$, to the hydro-dynamic lubrication at the speed of $n \geq 1200 rev/\min$.
The dependence of voltage on the electric current intensity in various regimes of lubrication is shown in Fig.5. Thus, for *n = 100 rev/min* the lubrication is limit; for *n = 200 rev/min* the



n = 100 rev/min *n = 200 rev/min* *n = 600 rev/min* *n = 1400 rev/min*

Fig.5. *Influence of rotation speed.*

lubrifying regime is mixed; for *n = 600 rev/min* the lubrifying regime is elasto-hydro-dynamic (EHD), while for *n = 1400 rev/min* the lubrifying regime is hydro-dynamic.
In the limit lubrifying case, voltages of $20...80 mV$ applied on the bearing lead to electric current intensities of $3...5 mV$. This phenomenon may be explained due to the existence of the contact between the roughness of the ball and that of the rolling race. Currents higher than $7 mA$ occur at voltages in excess of $0.2V$, and the voltage stabilizes itself around the value of $0.72V$.
When the rotational speeds range between 400…800rev/min, there occurs an elasto-hydro-dynamic lubrication, the balls being separated from the rolling races by a very thin film which can be easily broken through by the electric current.
When the rotational speeds are higher than 1000 rev/min, the lubrication is hydro-dynamic; at this moment there occurs a voltage peak which will break through the lubricant film, after which the voltage decreases, while the electric current intensity tends to continuously increase.

3. EEPERIMENTAL TESTS ON THE RIG WITH TWO BEARINGS

The experimental tests were made on 6206 2RS bearings, as they are frequently used in the construction of electric rotational machinery. The flowchart of the test rig is shown in Fig. 2. On this rig the measuring of the voltage and of the input electric current intensity, determined by the two serially connected bearings under test is done by means of a data acquisition plate, the data being subsequently processed using the PC soft – Lab VIEW. This rig eliminates the

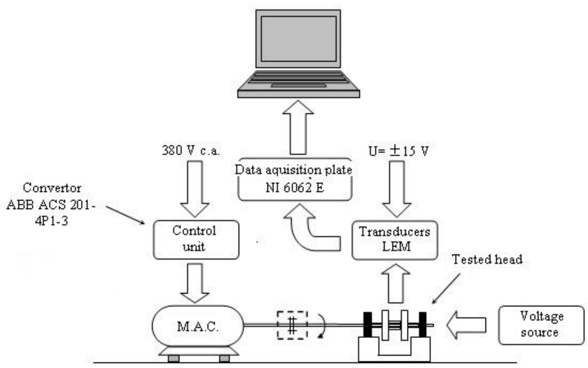
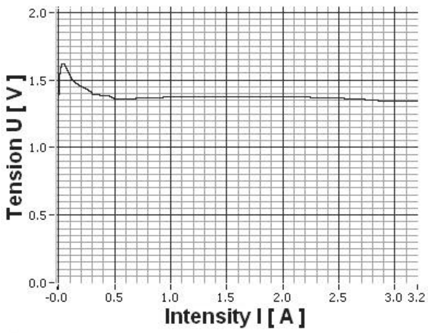
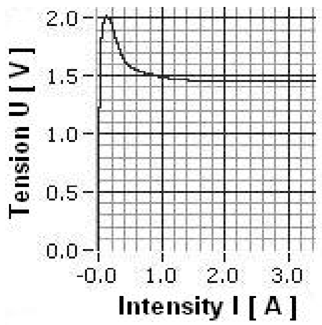


Fig.6. *Test Rig Flowchart*

errors in processing the experimental data introduced by the presence of the collecting bush which is serially connected within the electric circuit of the tested bearing.(Fig.1)
The first experimental tests conducted on the new rig implied the application of direct current voltage on the bearings. These first tests were highly influenced by the electric phenomena generated by the converter which fed the driving motor of the rig. After screening the converter connecting wires, the level of spurious frequencies diminished by approx.10 times. The total removal of these errors was achieved by introducing some filters for the voltage and the current applied to the tested bearings in the experimental data processing flowchart created with the Lab VIEW soft. This way we managed to plot the diagrams $U = f(D)$ very close to the ones obtained by processing the experimental results obtained on the rig with one tested bearing (Fig.7).



BEACON 325 lubricant
$n = 600 rev/\min \;\; F_r = 57.7N$



ALVANIA lubricant
$n = 600 rev/\min \;\; F_r = 57.7N$

Fig.7.

The test rig with two bearings (Fig.2) allowed us to conduct tests under alternating current conditions. A 50Hz alternating current obtained from an auto-transformer was applied to the bearings he variation in time of the voltage and the electric current intensities is presented in Fig.8.

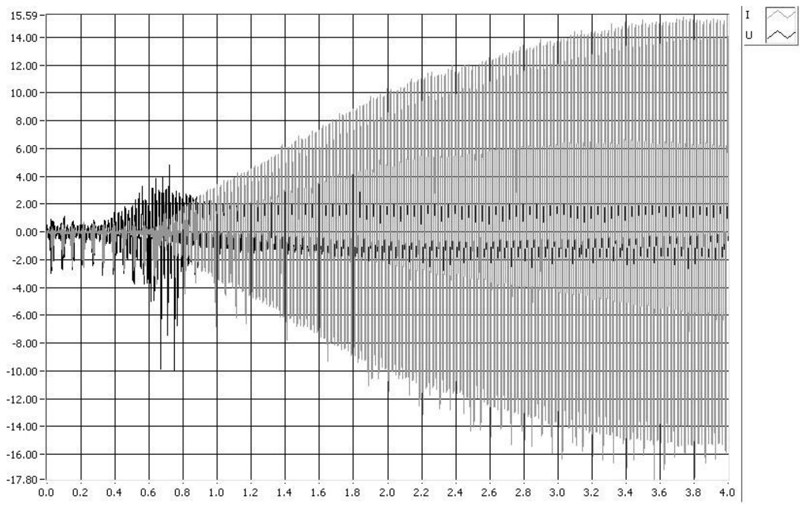


Fig.8. *Voltage and electric current variation in time.*

It can be seen that, initially, at low alternating voltage values, the electric current had low values, proportional to voltage. At a given moment there occurs the breakthrough of the film, when the current increases up to 16A, while the voltage becomes stable at 2V, although the operating knob of the auto-transformer is rotated in the voltage increasing direction.

The data acquisition was made without using the filters, so as not to distort the first experimental results. Details of the diagram presented in Fig.8 are given in Figs.9 and 10. The voltage variation is indicated by a solid line, while the current variation is indicated by a dotted line. The reading frequency of the experimental results was 150 kHz. On the diagrams' abscissa is indicated the number of readings in millions.

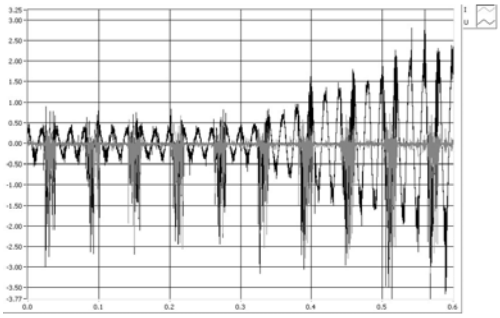


Fig.9.

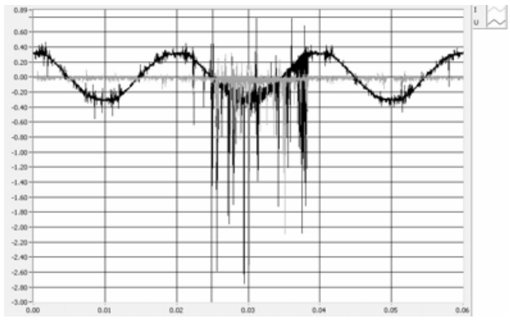


Fig.10.

5.CONCLUSIONS

The tests which were made on two rigs confirm the fact that the presence of an electric voltage on the bearing rings is a necessary and sufficient condition for the occurrence of an electric current which is on between the two rings by means of rolling bodies.
The tests were carried out under direct and alternating current, at various loads and revolutions. The lubrication of the bearings was made using lubricants of various resistivities.
The tests made in direct current showed a breakthrough voltage of the oil films, after which the electric current intensity tended to increase even if the intake voltage was constant or showed, tended to decrease.
Increasing rotation and lubricant resistivity determined an increase of the breakthrough voltage of the lubricating film, and the increase in the radial load led to a diminution of this voltage
The tests made in alternating current on the rig with two tested bearings has confirmed the same type of variation of voltage and current as it happened when direct current was applied.

6. REFERENCES

1.- A n d e r s o n S., *Passage of Electric Current through Rolling Bearings.* The Ball Bearing J., 153, (1968) pp.6 – 12.
2.- B o t o A., *Passage of Electric Current Through a Rotating Contact.* The Ball Bearing J. 153 (1968) pp.13 – 17.
3.- K o h n o A., *Relationship Between Electricity and Tryiology.* Japonese Journal of Tribology, Vol.41, 7 (1966) pp.663 – 669.
4.- P r a s h a d H., *Investigations of Corrugated Pattern, on the Surfaces of Roller Bearings Operating under the Influence of Electrical Fields.* STLE Lubrication Eng. 44 (8), 1988, pp.710 – 718.
5.- R a c o c e a C.C., L e o n t e P., R a c o c e a C.R., *Test Rig for Study of Phenomena Generated by the Electric Field Through the Rolling Bearings during Functioning.* 2nd World Tribology Congress, Vienna, Austria, 3-5 September 2001.
6.- R a c o c e a C.C., *The Influence of Variable Electric and Magnetic Fields on Reliability of Bearings in Electric Machines.* Doctoral Thesis, Technical University of Iasi 2003.
7.-, R a c o c e a C.C, P A L C, R a c o c e a C.R, *Estimation Of Energetic Losses In The Rolling Bearings Materials Under Alternative Magnetic Fields Influence,* Polytechnic Institute, Iassy, 2003.
8.- W a t c a n a b e T., I k e d a H., *Various Tribologycal Phenomena in Current Flow* (Part.1), Vol.41, 7, (1966) p.719 – 728.