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ANGULAR CONTACT BALL BEARINGS – A POSSIBLE WAY FOR ELECTRICAL CURRENTS IN MACHINERY. SPECIFIC TEST RIGS

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Abstract. *The paper presents a series of specific working conditions of working angular contact ball bearing in rotating electrical machines that lead to the passing of the electrical current through bearings. The electrical current, of different intensities that passes through the bearings during working, generates a lot of negative phenomena that lead to the substantial diminution of bearings life. For study of the phenomena generated by the passing of the electrical current through bearings, two test rig have been conceived, designed and built up. The paper presents the construction and working particularities of the rigs, as well as their performances.*

Key words*: Bearings Fatigue Life; Electric Current. Test rig.*

1. SPECIFIC FUNCTIONING CONDITIONS.

The great majority of electric rotating machines are equipped with ball or roller bearings. The presence of the electric current as well as the presence of the electromagnetic fields in the vicinity of bearings generate specific functioning conditions of bearings. The analysis of damage modalities emphasizes a multitude of possible causes of ball bearings failure. It is very rare that a ball bearing becomes failed due to a single cause. Generally, we are talking about a superposition of wear phenomena that influence one another, leading to the decrease of ball bearing fatigue life.

Frequently, the notion of reliability of bearings is associated with their functioning period till the appearance of pitting on the raceway or on the rolling bodies contact surfaces. The calculus relations shown in ball bearing catalogues reflect this tendency. Recent statistics show the fact that in concrete conditions, a small percentage of rolling bearings are damaged due to contact fatigue, their failure being generated by other causes. Thus, a statistics performed in the U.S.A. aeronautics industry, on a period of a ten years, shows the fact that only 2% of the bearings have been damaged as a result of contact fatigue. The majority of the rolling bearings have been damaged by corrosion (30%), or the wrong use of assembling instructions (20%). Similar conclusions were reached in the case of rolling bearing of electrical locomotives engines, where 7% of the bearings were damaged because of contact fatigue, 58% because of the presence of electric current and electromagnetic field, and 14% because corrosion.

The analysis of the ball bearings failures functioning in an electromagnetic field medium shows the influence of the damage of lubricant conditions. In such a situation the abrasive wear, as well as corrosion one, appear, and the internal clearance of the ball bearings, the noise and vibration levels increase beyond the admissible limit.

The passing of the electrical current through the bearings generates craters and ditches on the raceways and body surfaces. Craters are the result of electric discharges that take place intermittently among raceways and rolling body surfaces. This phenomenon is also called "electric pitting".

Fig.1. *Electric pitting on a ball.*

Fig.2. *Ditches on the raceway.*

The continuous passing of the electric current through bearings generates ditches on the raceway and rolling bodies surfaces that lead to the increase of friction and internal working clearance.
With no supervision, the bearings are totally destroyed, a fact that generates the serious damage of electric machine. Fig.3 shows two damaged bearings because of the continuous passing of electrical current.

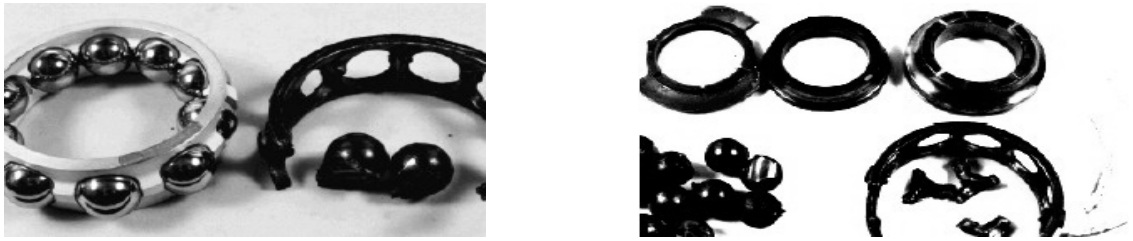

Fig.3. *Destroyed bearings.*

2. POSSIBLE CAUSES OF ELECTRICAL CURRENT PASSING THROUGH BEARINGS.

The performed researches emphasised the fact that the passing currents through ball bearings is generated by:

- non – symmetrical magnetic flux in the engine;
- non – symmetrical construction of magnetic circuit;
- the feeding of the engine with an alternative tension of variable frequency, from a frequency converter, **PWM** (**P**ulse **W**ith **M**odulated).

The first of the two causes are potential sources for generating of certain currents for any type of electrical engine (fig.4).

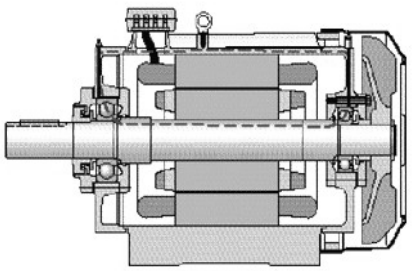

Fig.4. *Electrical engine penetrated by current.*

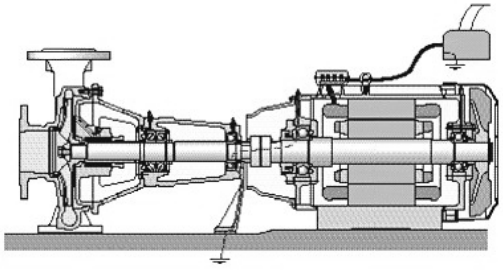

Fig.5. *Electrical engine fed by the converter.*

The non – symmetrical distribution of the magnetic flux in the engine induces axial tensions that generate low frequency currents through the ball bearings. The non symmetry of the magnetic fields generated by the eccentricity of the rotor and the deviations from the co-axiality of the bearings also induce low frequency tension that generates currents.
The last cause of generating currents through the bearings of the electric engines appears when using **PWM** in **V**ariable **S**peed **D**rives (**VSD**) that have been widely developed since 1990.
The feeding alternative tension of the electric engine may have frequencies from 3 to 20000 Hz, and the frequency of the harmonics has value between 5 kHz…10 MHz. The speed of tension increase, when using **PWM** has value between 5 and 10 kV/μs.
The currents generated by **PWM** can be:

- high frequency currents of ground connection;
- high frequency currents of circulation;
- capacity discharge currents

High frequency currents of ground connection are generated by the connection scheme at the exit of frequency converter (fig.5)
If the phase triphase alternative tension at the exit of the converter is different from zero, a movement of the neutral point appears. In the case of connection with the null being connected to the ground, it is possible to have the closing of a ground connected circuit. If the impedance of ground engine is too big, or an interruption of this connection appears, the current will close through the rotor, passing through the ball bearings shaft towards the ground connection on the converter (fig.5).
The electrical current penetrates the ball bearings through the lubricant film generated during functioning among raceways and ball surfaces. The residuum, the metallic impurities, the roughness of the surfaces and the geometrical deviations of the raceways and rolling bodies lead to the reduction of the ball bearing impedance, and, because of this, small potential differences can determine high values of the electric current. The effects of the passing of the electric current, finally lead to the destruction of the bearing.

3. RIG FOR EXPERIMENTAL TESTS.

For the study of the effects generated by the passing of the current through the ball bearings, two rigs for experimental tests have been conceived, designed and built up.
The scheme of the first rig is shown in fig.6. On this rig, the ball bearing 8, for testing, is placed

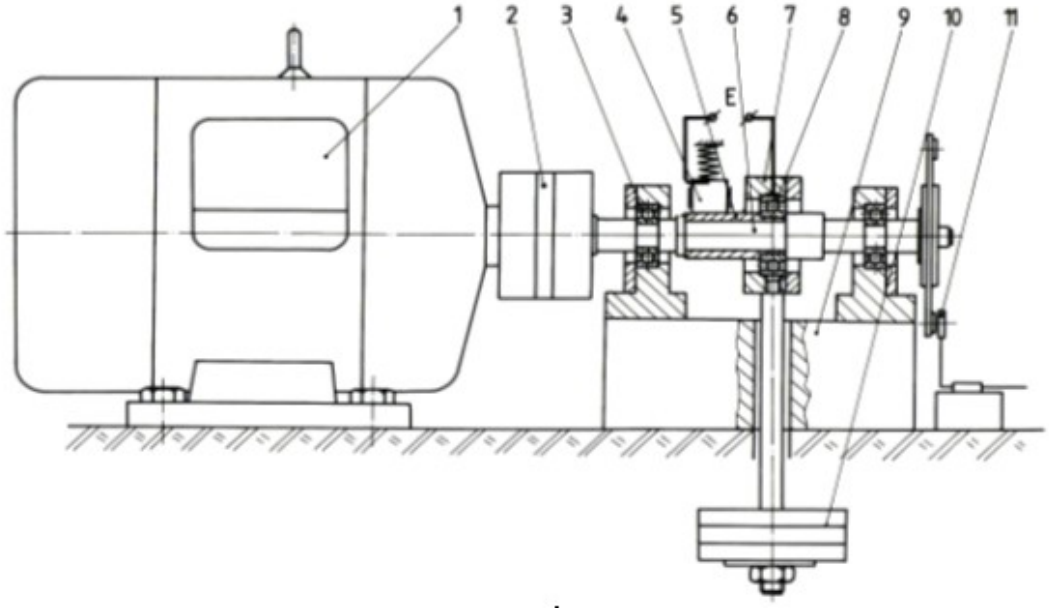

Fig.6. *Rig for experimental tests.*

on shaft 6 of the test head, by means of the bronze bush 5. Mainly, the electrical circuit of the current that penetrates the tested ball bearing is made up an E current source and closes by means the collecting brush 4.
The electromotor of continuous current (1), with mixed excitation, permits the obtaining of adjustable functioning rotating speed on a large scale by means of feeding the inducer with an adjustable continuous tension. The tested ball bearing is under an U tension, continuous or alternative, adjustable within large limits. The size of tension the (8) ball bearing is stressed with, during the tests, is measured with an electronic voltmeter, and the current, with an electronic amperemeter.
To reduce the contact resistance between the ring of the ball bearing and the pieces on which they are assembled, the exterior of the bush (5) and the interior of carcass (7) have been silvered. The electrical isolation of ball bearing (8) toward the electromotor (1) is obtained by means of bolt – disk coupling (2), whose semi - couples were made up of polyamide, and the electrical isolation towards the frame by means of holder (9), made of the same material as the semi – couples.
Besides the possibilities to adjust the rotational speed and the tension applied on the rings of the tested ball bearing, the stand also permits the charges of the radial changes of the ball bearing by means of weights (10). To obtain an adjustable changing load of the tested ball bearing, an electromagnet of continuous current can be used. This can be generated a constant, adjustable load or with transitory charge regimes. Using an alternative current electromagnet, we can generate a load with a constant component and an adjustable one, with an imposed frequency.
Using this rig, tests were made, stressing the tested ball bearing in alternative and continuous currents, with different revolutions and charges at which dependencies U = f(I) have been traced.
The main disadvantage of the above presented rig was the collecting brush (4) in the circuit of the tested ball bearings. The resistance of the collecting brush is comparable to the resistance of the ball bearing. At the passing of electric current through the circuit of the tested ball bearing, the collecting brush tends to change the phenomena of the passing of current through the ball bearing.
At the same time, the rig does not allow the passing of the currents of capacity discharge owing to the tendency of soldering between the collecting brush and the bronze bush. These elements lead to the modification of the previously presented rig and the realization of a new one with two tested realization of a new one with two tested ball bearings serially connected from the electrical point of view (fig.7).

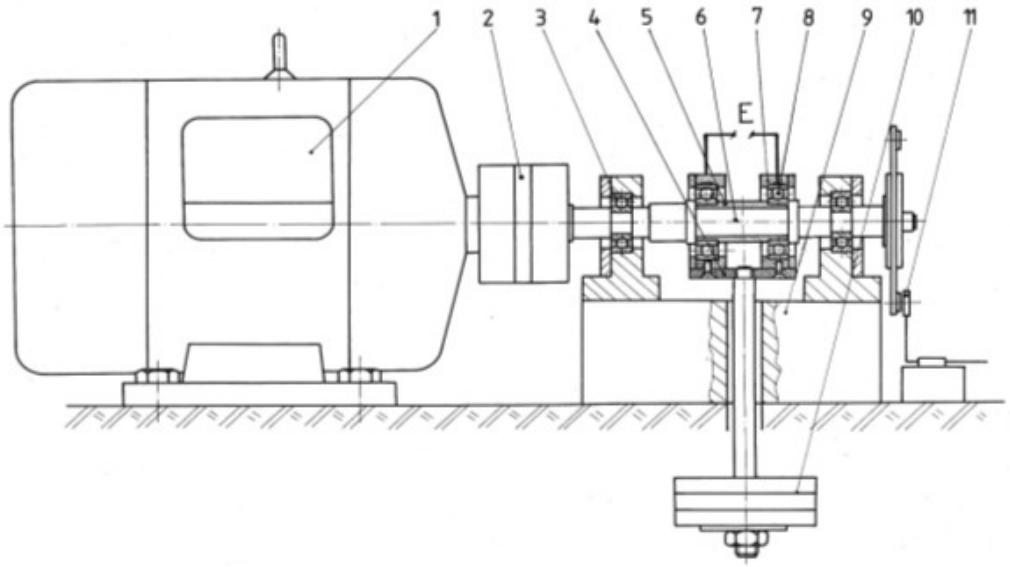

Fig.7. *Rig with two tested ball bearings.*

The movement and the torque are transmitted from the electromotor (1) to the shaft (5) of the test head, by means of bolt coupling and disk (2) made of electro-insulating material. The shaft (5) rests on two line-shaft bearings (3) braced to the base-plate (9) that is made up to the same non-conductive material as the coupling is. Thus, the test head is totally insulated from the electrical point of view, from the rest of the rig.
The two tested ball bearings (8) are placed on a bush (5), made of bronze. For a better electric contact, the surfaces of the pieces that are in contact with the tested ball bearings have been silvered.
The radial charge of the tested ball bearings is performed by means of weight (10), fixed on the plate (4), made of textile laminate wafers.
The electric current generated by E source is closed through the carcass of one of the tested ball bearings, passes from its other ring to the inner one, through balls, and from here gets to the bronze bush (5). After this, the current passes toward the inner ring of the second ball bearing, penetrates it by means the rolling bodies and closes through the carcass of the second tested ball bearings.
If plate (4) by means of which the radial change of the tested ball bearings is accomplished, were not be made of textile laminate wafers, but of steel, the circuit would be closed between the carcasses of the bearings through this plate, and the study of the phenomena generated by the passing of the electric current through the ball bearings would not be possible.
The measurement of the tension and of electrical current applied on the tested bearings is accomplished by means of a voltmeter, respectively an electronic amperemeter. To increase the precision of the tests, installed of these measurement devices, an acquisition plate can be connected, and the results will be stocked and processed by computer. Thus, the influence of continuous, alternative or pulsating currents, as well as the consequences of the electric shocks generated by the capacity discharges can be also studied.
The tests will be made at different radial loads, by modifying the weights (10) and at different rotational speeds generated by the electric motor (1), fed from a frequency converter. The measurement of test rotational speed is made by the electronic remitter (11).
The two rigs in the testing laboratory are shown in photo 1 and photo 2.

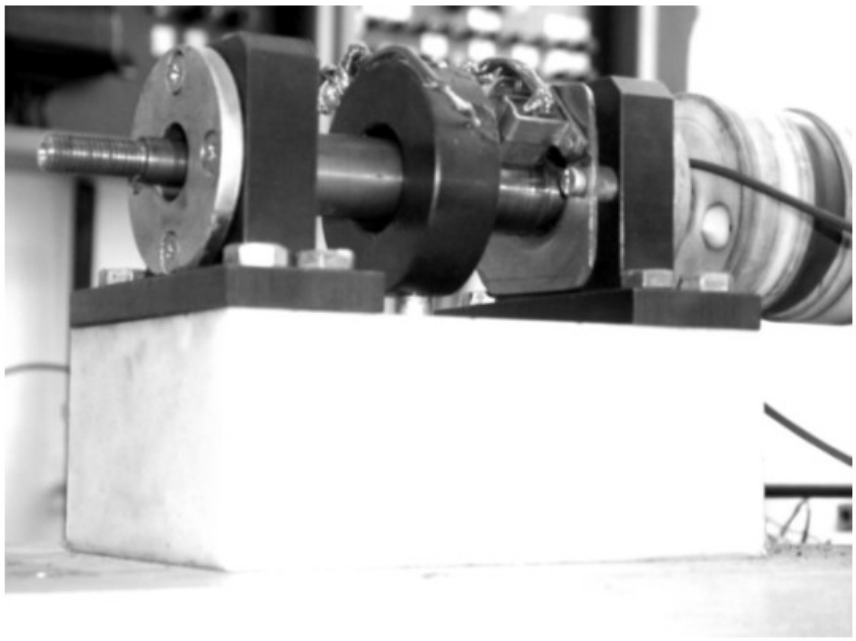

Photo 1. *Test rig with one tested ball bearings.*

Photo 2. Test rig with two tested ball bearings.

4. CONCLUSIONS.

The use of rotary electrical machines proves that, in the majority of cases, the bearings are penetrated by electric currents with different intensities. The existence of potential difference between the shaft and the carcass is a sufficient condition for the appearance of a current that will penetrate the bearing.

The passing of the current through bearings generates a series of negative phenomena that substantially contribute to the diminution of their durability. Practically, the ball bearings of electrical devices are out of use through electrical pitting, electro erosion, damage of raceways and rolling bodies surfaces, degradation and impurification of the lubricant etc. The mentioned aspects imply the study of the effects that are generated by the passing of the electric current through bearings during the working.

With this purpose, two stands for specific tests have been conceived, designed and built up. The working and test particularities allow a large scale of experimental data.

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