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# DIAGNOSTIC OF BEARINGS OF ELECTRIC MACHINES

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**Abstract** – Recently many articles discussing about shaft voltage and bearing currents and about their influence on operating life and reliability of sliding and anti-friction bearings appeared. Negative influence of elecric current passing through bearings is known from beginning of the last century but new problems were occured with assotiation of electric machines feeding from static frequency converters. And just this problem is described in the article. We want to show our results of laboratory experiments and mathematical analysis of bearings damage in this paper.

**Keywords**: converters, machines, bearing currents

## 1. INTRODUCTION

A bearings working time is influenced by many factors – defective mounting, incorrect choice, dirtiness, incorrect lubrication, heavy load etc. It is always very difficult to implement right diagnosis, especially by actuating of several stresses simultaneously. Because in the case of bearings concern mutual rolling or sliding of two bodies, comes to degradation of bearings of electrical machines by abrasion.

It comes to degradation of bearings by electric machines often after short time. Wave cavities periodically repeating are noticeable on the orbits of bearing rings. The rollers or balls surface has no by eye distinguishable grooving or another damage. The grooves and craters are clearly distinguishable by enlargement. The abrasion is an undesirable surface or dimension modification of solids caused by interaction of functional surfaces or functional surface and abrasion producing medium. Chemical, electrochemical or another actuation can attach these effects.

Electrical abrasion of bearings is complex of electrical, electroerosive and electrolytic abrasion.

- electric abrasion is abrasion rising by continuing electric current passing through bearing. This fact is supported by permanent contact of rings and rolling stouts. Contact places are created by single small flats.
- Electroerosive abrasion is abrasion incurred by spark or arc discharges.
- Electrolytic abrasion is abrasion originated by electrochemical action in bearing

Also bearing current comes under quantities degradating functional quality of bearings of electric machines. Current passage causes damage of bearings in the place of contact among rolling bodies and orbits of inner and outer ring and by slide bearings damages surface of bearings pans (composition) and shafts. Current passage can also damage quality of lubrication materials. Voltage origin causes current origin and shaft voltage occurs between shaft ends or between shaft and ground. This effect is known as long as the electric machines are known, that means more than 100 years but it occurs in this time more often in the connection with electric machines by feeding from static converters. It concern both DC motors fed from static rectifiers and AC motors fed from frequency converters. Bearing currents can also be originated by motors supplied over nonshielded cables.

Electric current flows through the circuit created by outer ring, rolling body and inner ring of the bearing.

The electric distortion of lubrication layer at both bearings ( four times ) must come by the axial current flow through the shaft (see Fig. 2). The typical damage of bearing by current passage is defined with difficulty.

The appearance of bearing orbits and bodies will be depended on a magnitude and time of current passage, sparks or arc discharges, current density in the place of current passage, lubrication state and quality, loading time, type of motor current etc. A bearing damage is influenced by mechanical load of bearing but to bearing damage can also come by small mechanical loads.

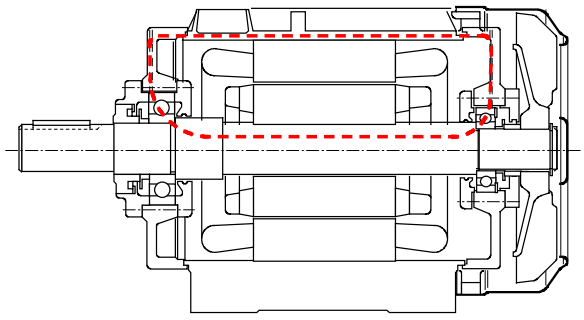

Fig. 2. Circuit of bearing current

## 2. MEASUREMENT AND DIAGNOSTICS

As it is a common state that by any detection of object functional properties or failure cause there must be kept at disposition a measurable quantity and just the word "measurable" make very often great problems. And it is not only that. We must know again or define a magnitude or bounds of the quantity. They must be tolerable by failure-free operation of the object.

We chose in our case the shaft voltage and currents flowing across electric machines bearings for failure causes detection of slide and anti-friction bearings.

The shaft voltage measurement is more simply. That means we have in mind both a real shaft voltage $U_H$ and the shaft-ground voltage $U_{Hz}$ - see Fig.3. Though this voltage is measurable by common voltmeters there is more suitable to record a voltage course by oscilloscope and to make analysis of records. A magnitude of voltage course is evaluated and apart from other defects or failures can be detected by the course analysis.

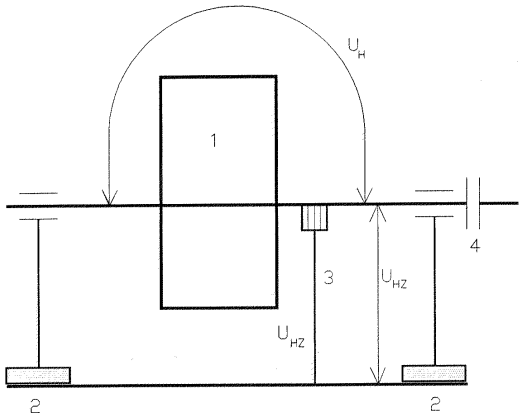


Fig.3. Shaft voltage demonstration

The measurement of bearing currents is very difficult. The reasons are not in their magnitude or course but in the possibility of positioning of suitable current sensors into the current circuit. Because the current magnitude increases with motor power magnitude, a measurement of middle or great power motors will be apparently more easy. A machine shaft is the most suitable place for current sensor positioning(e.g. Rogowski coil). This fact requires a machine dismounting and machine shields modification or only their parts in all cases. And we can measure only current produced by motor nonsymmetry. The next possibility is at least one shield modification of the machine to create a defined path both for currents caused by unsymmetries and by capacitive currents. This method means essential motor frame modification.

We also tried to measure current on partially dismounted motor. A rotor with bearings was inserted in a stator without shields and bearing caps and a rated air gap between stator and rotor was created by rotor underlaying. The motor shield was replaced by copper conductors for circuit closing. It is evident that measure was executed without rotor rotating and under smaller voltage than rated motor voltage. Common split-core current ammeters with output to oscilloscope or Hall probes are sufficient in this case. For obtaining of more exact information about possible damage bearings mechanism there was a mettalographical analysis executed by method of light microscopy and scanning electron microscopy. A material surface was studied and in some cases metallographical scratch patterns were evaluated. Metallo-graphical evaluation was executed by bearings operated on motors at industrial conditions and by bearing loaded by defined manner at laboratory conditions (current passage and electric discharges). There were observed outer and inner rings damage and also ball or rollers by bearing operated at industrial conditions. It is concerned about damage of groove, craters or micro-craters type, first of all on balls and rollers and about grooving on orbits of outer and inner rings. An example of surface damage is documented on Fig.4. There is a ball surface with noticeable grooves. There were appeared also micro-craters by enlargement of this picture.

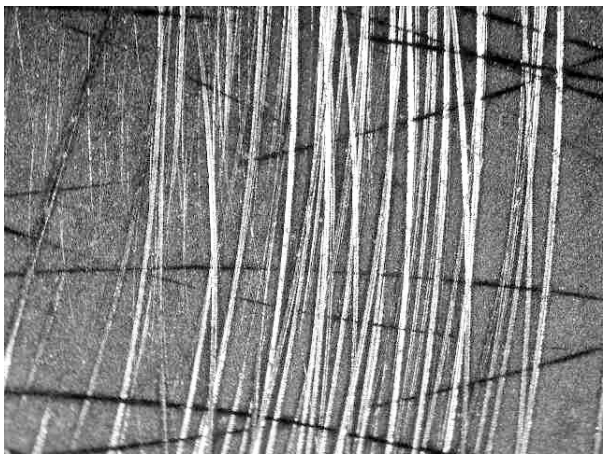

Fig. 4. Grooving on ball surface

In the case of bearings loaded at laboratory conditions there were concentrated an attention into two examples. A bearing loaded by AC current 50Hz without electric discharges and a bearing loaded by AC current but in the form of electric discharges. These two methods of current passage over bearing correspond to real conditions. By origination of bearing currents caused by machine magnetic or electric circuit asymmetry and by electric breakdown of lubrication film comes to stable current passage.

In the case of motors supplied from static frequency converters concerns mainly electric discharges caused by capacitances in the circuit converter - motor. An axial grooving on outer and inner ring was observed by a bearing loaded by AC current 1A during test time hours. A surface view is documented in the Fig.5.

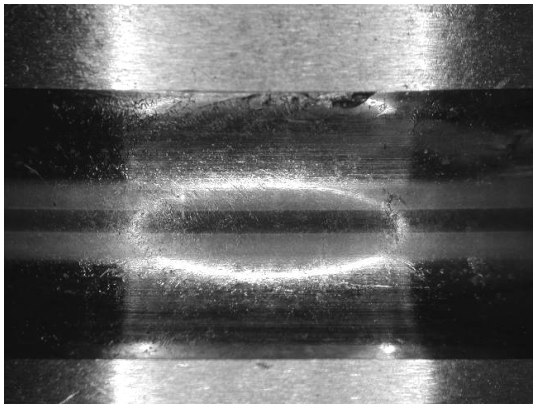

Fig. 5. Surface of inner ring loaded by AC current

The workplace was arranged at laboratory conditions where at free shaft end of asynchronous motor a tested bearing was placed and by the help of slide contact brush-copper ring on the shaft and electrode on the outer ring of the bearing an alternating current 50Hz passed through the bearing. The voltage magnitude by that comes to breakdown of lubrication film was probed at first.

## 2. THEORY OF RUBBING SURFACE ORIGINATION

By common working of bearing there is a thin tier of lubricant between rolling body and ring. The thin tier behaves as insulator and protects current passes through the bearing if voltage between ring and rolling body does not get over limit dielectric strength of this tier. If vibration actuate on bearing, lubricant is pressed up in the places of beats, and this is the first assumption for ideal place of current passing through. In other places on the contrary the insulation strength increases with lubricant thickness. Passing current is concentrated on only certain places. These places are heated by current passing. As a result of that there is a change of a metal surface structure.

The only change of metal surface structure changes its mechanical characteristics (strength decreasing and toughness increasing on the contrary). The heat, that is generated by electric discharges, causes a local melting of slide surface. From the created craters the metal particles are released and these particles can travel on the surface as shown in the Fig. 6.

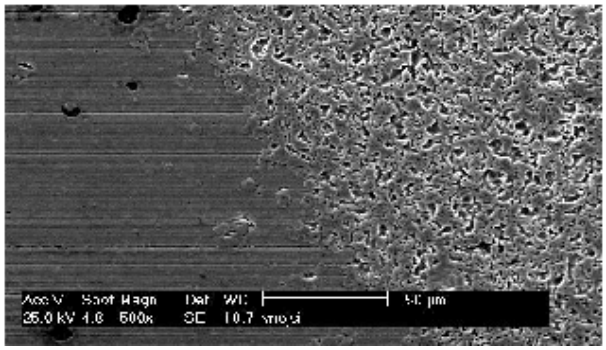

Fig. 6. Enlarged surface of the ring

The small craters are again hardened but they are more brittle on the contrary of the basic material. The damage can show as pitting or slotting (washboard), the cross gray slots of shiny appearance and possibly with marks of melting. The areal shape of these slots is given by axial and radial shift by bearing bodies.

As a consequence of that the mechanical oscillations are produced by dynamical effect of rolling bodies rolled over the craters. The slotting of its own is not originated as result of electric current passage or discharges, but it is about subsequent damage of bearing rings surface as a consequence of originated craters. The craters are obvious also on the surface of the rolling bodies. The size of craters is about µm.

We can say, that there is only one of the possibilities or damage causes and therefore it is possible to consider every accident of the bearing.

To better understand of mutual binding of inner and outer ring and rolling bodies, we try to simulate a tread of the crater due to e.g. by a discharge to inner and outer ring by rolling of one ball.

The defective points are treated alternately on the outer nad inner ring by bearing rotation. The defective points rotate with inner ring with speed w. The result of this technique is in the Fig. 7, where is shown a front panel of application created in LabVIEW with visual demonstration of prints on the both rings. In this case should be created five prints on the inner ring and seven on the outer ring by this bearing. Then the points started to be retyped.

To verify this calculation, there was created another algorithm for printing of calculation number by the help of software MathCAD. A model was not created by the help of coordinate system transformation to polar coordinates for this once, but by the help of algorithm with cycles and conditions of logic operators and whole multiples for the same bearing dimensions as they were assigned in LabVIEW.

Ball radius: r2 = 20mm

Inner ring radius: r1 = 100mm

Outer ring radius: r3 = r1+2r

r3 = 140mm

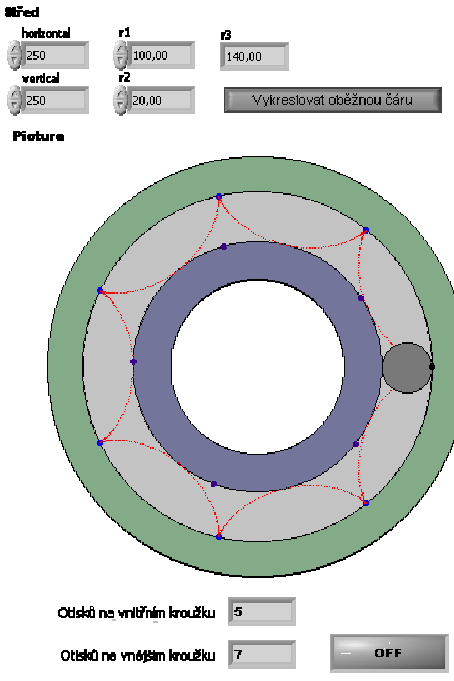


Fig. 7. Simulation of ball movement in the bearing

The result for inner ring (r = 0)

A(0) = 5

The result for outer ring (r = 1)

A(1) = 7

Because a bearing with only one rotating body does not exist, it is necessary to regulate the calculation for

possibility of use of more rotating bodies and then by an enlarge of previous calculation the real bearing model calculation was created by help of common dividers of print and rotating bodies numbers.

Balls number : 12
The result for inner ring (r = 0)
X(0) = 60
The result for outer ring (r = 1)
X(1) = 84
This result was not verified by the help of simulation yet, because the algorithm assembling is more complicated.

## 3. CONCLUSIONS

Some new tests and measurements of asynchronous motors bearings were presented in this paper. The results of measurements on asynchronous motors supplied from frequency converters are very interesting. There are documented damage of bearings by microscope copies and measured bearing currents. Mentioned results of our research acknowledge demand factor of reason determination of bearings functional properties. We are furthermore engaged in electrical properties of lubrication film in a bearing.

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