

INFLUENCE OF ELECTRIC DISCHARGES ON BEARINGS OF ELECTRIC MACHINES

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Summary In the last time many articles were found out discussed about shaft voltage, bearing currents and their influence on lifetime and reliability of electric machines bearings. This is associated with extension of use of static converters for control drives for DC motors feeding in the past and for induction motors feeding from frequency converters in the last time. It is known from our own experiences that not all failures assigned to bearing currents were their real reason and we also know how hardly the mentioned currents can be measured on real machines and how work-intensive and expensive is to detect real reason of the failure on damaged bearing. We will not concern with basics of classical bearing currents in this paper, because they were known and studied in the beginning of the last century but our own investigations will be presented.

1. INTRODUCTION

Because we had just been meeting for several years with demands on explanation of bearing failures reason and on influence of feeding of induction motors with non-sinusoidal voltage on this effect, we have started to concern with these problems. The causes of the shaft voltage and currents bearings origination were studied the analysis of bearing failures from crashed motors and also of prevention of these failures were made. Our results of experimental tests will be introduced in this paper. The tested bearings were loaded by a defined manner approximately corresponding to stress of the motor fed from frequency converter and then an analysis of bearing rings and rolling bodies were made.

2. BEARING DAMAGE DEMONSTRATION

A bearing lifetime is influenced by many factors – faulty installation, wrong choice, dirt, wrong lubrication, great load etc. It is very difficult to make

a right diagnosis mainly by influence of several simultaneous stresses. Because in the case of bearings it is about reciprocal rolling or sliding of two bodies it comes to degradation of the machine bearings by damage.

It comes often to bearing failures by electric machines after a short operation time. An example of damaged bearing of electric machine is shown in the fig.1. In general we can say that periodically repeated waves depressions are mostly evident on the surface of rolling ways of bearing rings – fig.1. A surface of rollers or balls has no grooving or other damage recognizable by eye but by enlargement the grooves and craters are clearly visible – fig.2.

At laboratory conditions the series of experiments were made to investigate an influence of electric current on bearing lifetime.

An influence of steady current passage through the tested bearing connected into electric circuit in according with fig.3 was monitored. A current of 1A passed through a bearing during a period of 300 hours. The appearance of inner surface of outer ring after bearing dismantling is shown in the fig.4.

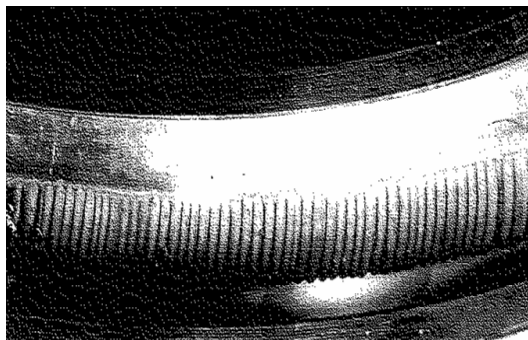


Fig.1. The surface of rolling ways of bearing ring



Fig. 2. Surface of ball

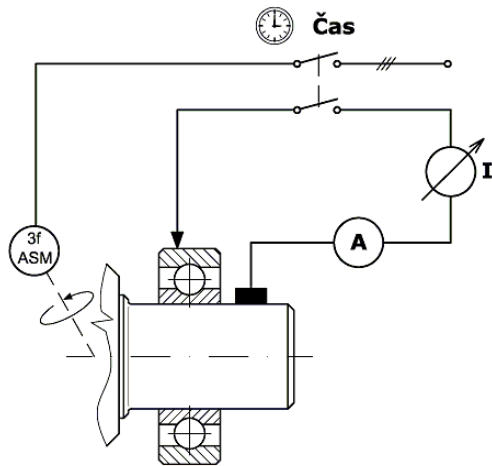


Fig. 3. The testing circuit of bearing

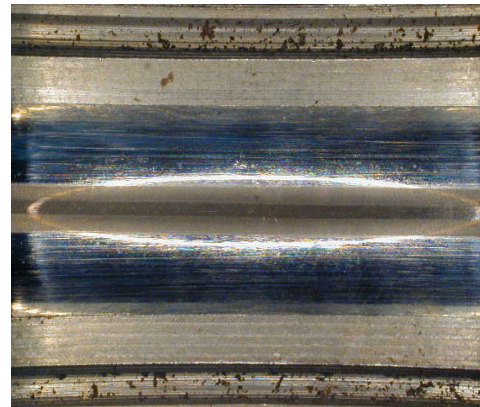


Fig. 4. The damage of ring by current

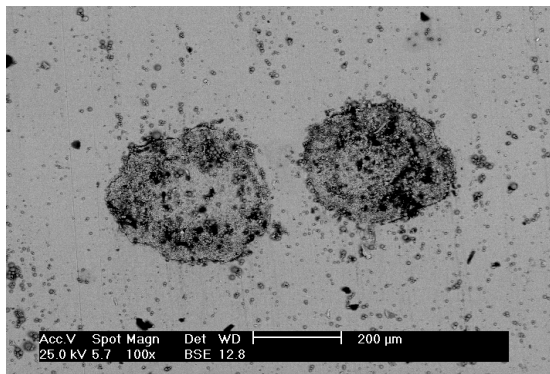


Fig. 5. Disturb of outer ring orbit surface by two testing discharges

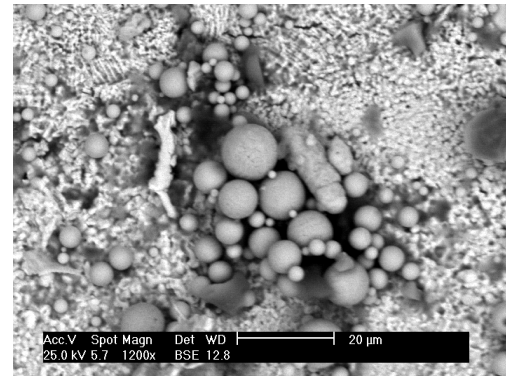


Fig. 6. Disturb of outer ring orbit surface by two testing discharges by enlargement

Feeding from frequency converter is known as one of the possible cause of bearing current origination. It comes to electric discharges by influence of capacity in the circuit formed by motor, wiring and converter. The electric discharges disturb surface of rings and rolling bodies by penetrating of lubricating layer.

Disturb of outer ring orbit surface by two testing discharges is shown in the fig.5 and by enlargement in the fig.6.

Different character of bearing damage by steady electric current and current discharges is evident.

3. METALLOGRAPHY ANALYSIS OF DAMAGE

If detailed microstructure analysis of surface samples was made we can usually submit that only parallel grooves from tooling are evident in the part of rings which are not in contact with rolling bodies. In the damaged part the surface is crisped as it

would be compound from great number of small half-ball particulars. Small depressions are on the surface in another part with small half-ball particulars settled in them. It is usual martensitic structure with fine carbide particulars typical for given steel. A thin non-corroding layer is appeared on the surface. Microanalysis indicates that non-corroding layer corresponds to the bearing steel by chemical structure. It is evident that is no foreign material.

The damage of bearing by grooving is shown in the fig.7. This damage is often marked as influence of bearing currents. Detailed figure (fig.8) indicates on mechanical damage or great concentration of small current pulses which smelted the surface but only to such a degree that due to reduced strength the material could be partially pulled up from the places. The cause of this state could be voltage induced by unbalance due to slotting. Experiments described below were realized for explanation of damaged causes.

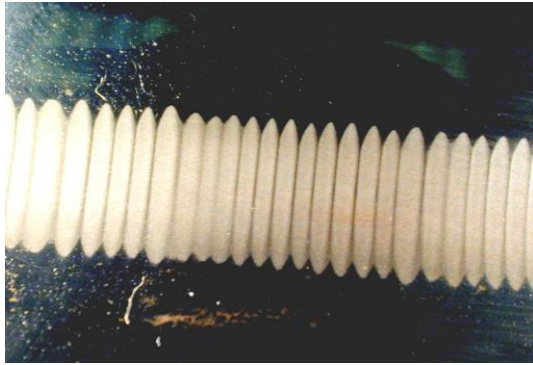


Fig. 7. The damage of bearing by grooving

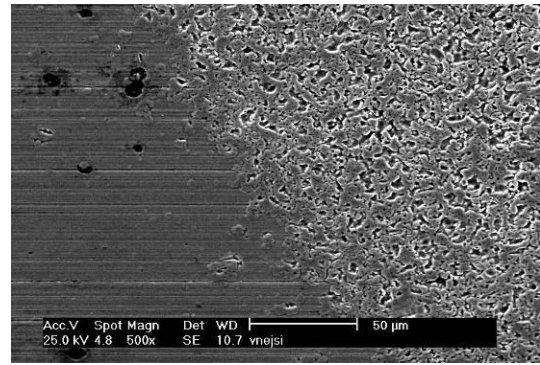


Fig. 8. Detailed figure of damage of bearing by grooving

4. RESEARCH OF INFLUENCE OF DISCHARGE ACTIVITY

Discharge action was investigated. Discharges were generated by voltage appeared on the motor frame because the motor was fed from frequency converter. Our testing workplace is shown in the fig.9. Tested bearings were on the shaft of the running motor and from the frame of the second motor fed from frequency converter the voltage was brought to the bearing inner ring. Outer ring of the bearing was grounded. Tested bearings were cut up after 100 hours of operation with voltage stress and analyzed then.

Transient effects originate by feeding of induction motor from frequency converter by switching processes corresponding to RLC circuit parameters. The RLC elements are defined by construction setting of winding at stator packet. Fast time changes of voltage ($10\text{kV}/\mu\text{s}$) applied to winding terminals produce charging and discharging transient effects accompanying the slot insulation polarization. In the case the motor is fed from frequency converter in IT network, an electric potential originates on the motor frame with the course of sum of three voltage courses. The voltage course in our case is shown in the fig.10 by converter adjusting 25Hz of output frequency and 4 kHz of switching frequency.

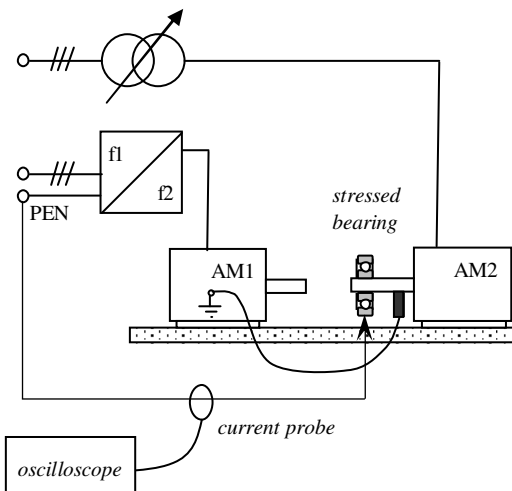


Fig. 9. Detailed figure of damage of bearing by grooving

Hybrid, standard and insulated bearings were stressed by mentioned voltage course. A standard bearing was also tested without electric stress for compare.

Hybrid bearing had no damage after 100 hours operation with the stress of voltage pulses. When the standard bearing of type 6206ZZ was tested then after 60 hours of operation was damaged and vibration and noise were registered. A course of the current passed through the bearing was measured and is shown in the fig.11.

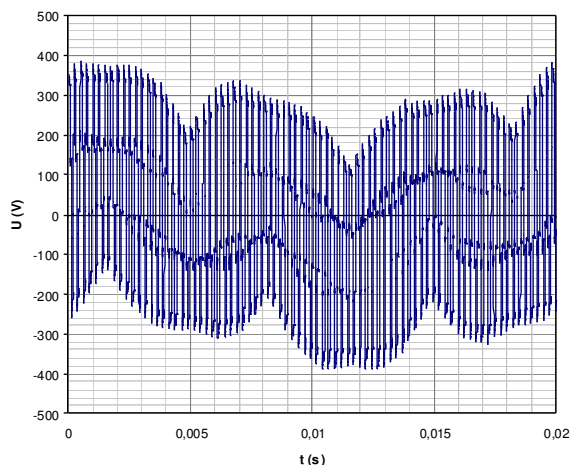


Fig. 10.a The voltage course on motor frame

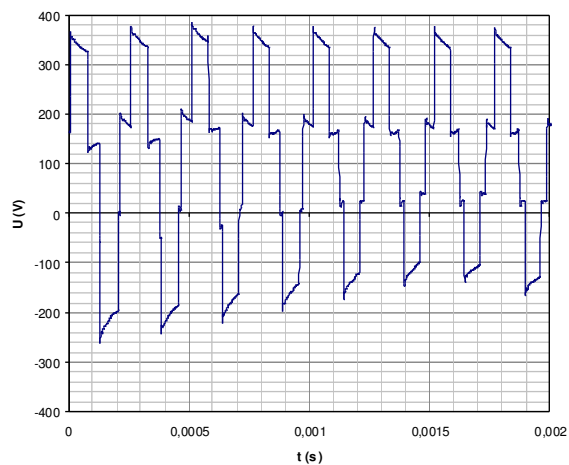


Fig. 10.b The voltage course on motor frame

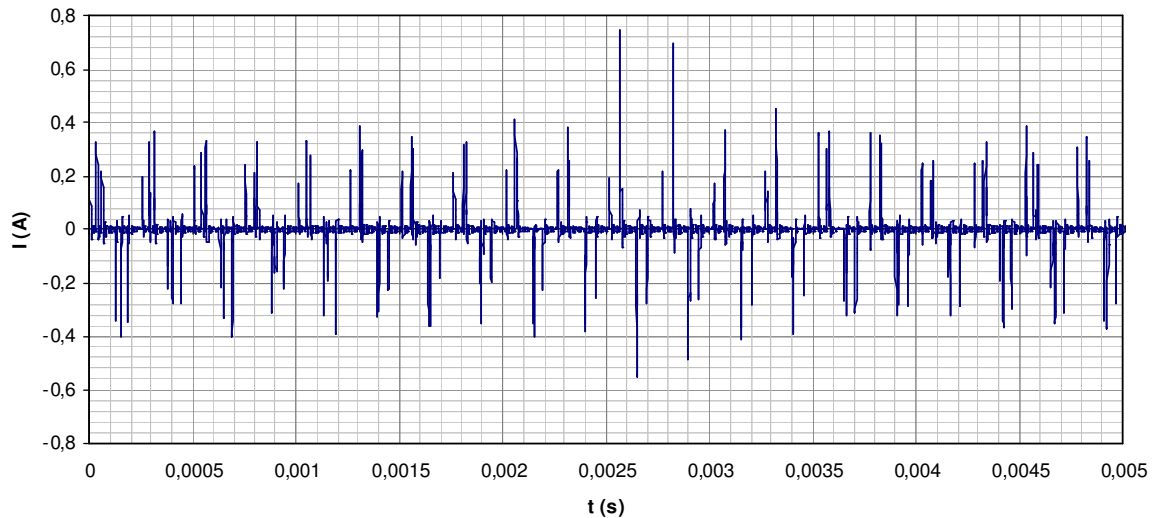


Fig. 11. Course of the current passed through the bearing



Fig. 12. Damage of inner ring orbit

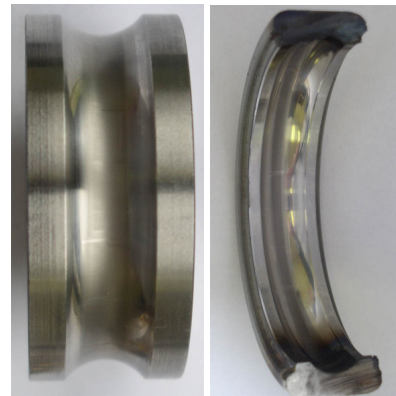


Fig. 13. Damage of insulated bearing after 100 hours of operation

The damaged bearing was cut and analyzed with result of large damage of outer and inner ring orbits – fig.12. The bearing lubricant was also depreciated.

This damage was then confirmed by metallography investigation. A similar damage was observed by insulated bearing after 100 hours of operation (see fig.13). The standard bearing 6206ZZ was then tested without voltage stress for evidence that damage was really created by electric discharges. After 100 operating hours the bearing was analyzed- The surface of outer and inner ring were without damage. At last the test was repeated with the standard bearing and voltage stress. Vibration and noise progressively increase and the bearing was damaged after 100 hours.

5. ANALYSIS OF STANDARD BEARING STRESSED BY ELECTRIC VOLTAGE DURING 60 HOURS

The samples of outer and inner ring, ball and cage were analyzed after bearing cutting. The photography documentation was made for small magnification by stereomicroscope. A matted area was observed by sample of the outer ring in the place of probably contact of the surface with balls. The matted area was about 1/3 of the orbit width. A damage of inner ring sample was also observed. This damage reminded a “rubbing-board” but not so typical. The flutting was appeared on the surface of the sample whereas width and length of bands is different. Areas with periodically different width and length were appeared. Type of damage of inner ring is shown in the fig.14, of the ball in the fig.15 and of the cage in the fig.16. The signs of mechanical damage and plastic deformations of the surface were shown on the cage (fig.16).

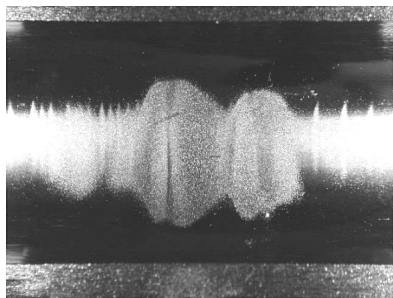


Fig. 14. Inner ring 10x



Fig. 15. Ball 45x

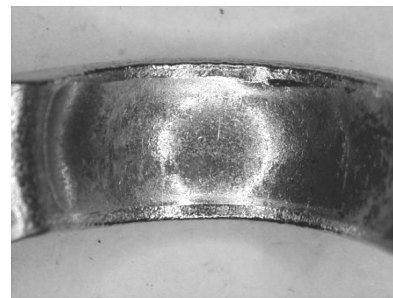


Fig. 16. Cage. 12x

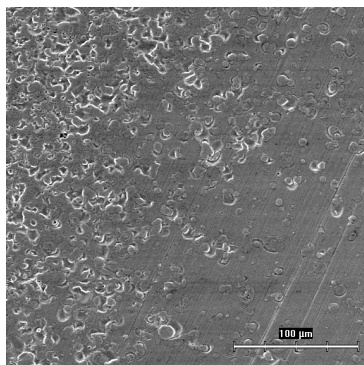


Fig. 17. Outer ring

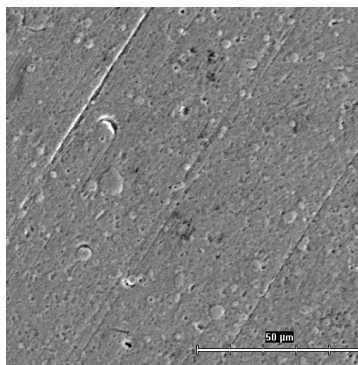


Fig. 18. Inner ring

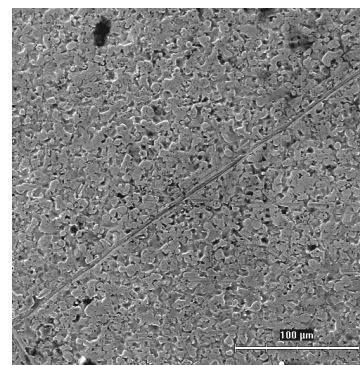


Fig. 19. Ball

Detailed analysis of the samples was made by the method scanned electron microscopy. Two different areas were found on the samples of the outer ring. The area with undamaged surface only with small mostly parallel grooves due to tooling and the area of inner ring orbit with crisped surface. It looks to be a thin layer of the new material (fig.17) with noticeable transition between damaged and undamaged part. A similar situation was registered by inner ring too. A layer of new material is stuck in the part of flutting. The undamaged part had only fine grooves given by tooling. An edge of flutting is shown in the fig.18. The rest of grooves are notable on the surface and started to be covered by a layer another material. The ball was crisped on the whole surface with a thin layer of another material(see fig.19).

The microstructure of rings and ball samples is martensitic with very fine particles of carbides uniformly distributed of metal matrix. No marked structural modifications were observed under surface in the place of supposed contact with balls.

6. CONCLUSION

The feeding of asynchronous motors from frequency converters will be next extended and so the cause of bearing damage must be known. It

is necessary to know the material transfer theory in the bearing, to deduce methods for their elimination. It is evident from executed experiments that changes disturb slide surface of outer and inner ring and also a lubricant. We can simply say that the main manifestation is material layer on the balls and rings surface in the parts of probable contact with balls.

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