INFLUENCE OF ELECTRIC DISCHARGES ON BEARINGS OF ELECTRIC MACHINES

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Summary Bearing currents are one of cause's bearings faults. The character of a lubricator belongs to main factor influencing an inception of bearing currents. We have analyzed the electric character variety kind of lubricators; the influence of lubricators on a bearing current was analyzed too. Some results from the mentioned research are introduced within this paper.

1. INTRODUCTION

For definition inception time of bearing current, source of bearing current, condition of current passage through the bearing and last but not least the size of bearings damages, is necessary to realize the detail analysis. The analysis of character and construction of bearings, the process of lubrication and production of oil layer is important and needful procedure. The lubricant decreases an abrasion and corrosion, the lubricant is used for restriction of impurities too. The lubricant creates the oil film between roller bearings and circulating lines. The oil film of the lubricant prevents the direct contact between the metal part of roller bearing and circulating lines also at the high load.

The viscosity, the ability of the oil film formation and the consistence belongs to important characters of lubricators. The thickness of the oil film is depending on the revolutions per minute, temperature and viscosity. The oil film take to surfaces that have be separated. All of mentioned lubricants characteristics affect the most important character on the part of bearings currents; that is breakdown strength of lubricant layer forming at rotating bearing.

2. ELECTRIC CHARACTERISTICS OF BEARING

The bearing has character as a non-liner element depending on variety of running conditions, actual state and design of bearing. The serial-parallel wiring of resistor, capacitors and bidirectional diode thyristor is used for description bearing, see Fig. 1. Branches at circuit with index elements 1....N ever describe one electric way from the inner bearing via the rolling element to the second bearing. The number of parallel branches N is equal to the number of rolling elements [1].

• The resistance R_{ki} is the contact resistance of a rolling element with the sequence i (the resistance of current straits and the resistance of foreign layers)

• Capacitors C_{vi} describe dielectric characteristics of the oil film between roller electrodes outer bearings-rolling element and rolling element-inner bearing of rolling element with the sequence i.

• The semiconductor element bidirectional diode thyristor D_i describes specific dielectric strength of a capacity C_{vi}.

In case, when the bearing rotates by nominal revolutions per minute, the layer of lubricant should be exists. This mentioned lubricant layer is considered as a dielectric between two metal electrodes. The lubricant layer forms capacitive layer connected in the circuit with serial resistors of current straits. These capacitors are ever two at branches, because ever two contact places on the one rolling element in the bearing exist. The scheme in Fig. 1 is simplified, for the one branch correspond one contact outer bearing-rolling element-inner bearing.

3. RESISTANCE OF CONTACT

Electrically conductive contact through the bearing is not possible in the case of correct lubrication of rolling bodies. But there are some metallic bridges in the real operation of the bearing. Current passage through intersection changes of current path take effect of heat and force result.

The commercial steel has 0,1÷0,18 $\Omega mm^2/m$, this is c. 10mutiple of copper resistivity. In concretely true value of specific electric resistance of bearing steel is not known, yet to be this property important influencing to heat making in contact point.

The resistivity calculation of current straits is coming from contact spot size of stationary contact. From microscopic angle the contact spot is making by metallic bridges [1]. The resistance calculation of current straits is problematic from view of radius definition of spherical surface or more precisely radiuses definition of elliptical surfaces of contact spot. There are three spot kinds of curved bodies: dotted, linear and surface. The surface profile of contact is dependent on surface curvature of both

bodies in contact spot. The contact surface is sphere when contiguous bodies are circular or elliptical when main curvatures are slowly and always changing of each body.

In case the current passage is in contact spot then some quantity of heat energy are originating by size of contact spot resistance and value of current square witch passes through. In detail view of current density and heat produce are values about 90kA/mm^2 in area border of contact spot. Attached omission heat removal to material, these values can warm up to 700°C [1] the contact spot for 10μs. It is due to curvatures and compression lines of current in this area see Fig. 2. The situation around rotating bearing is more complicated.

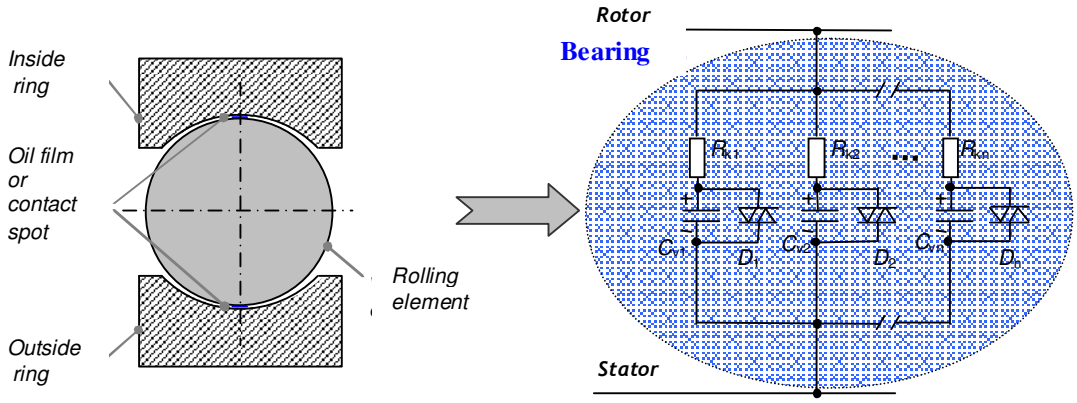

Fig.1. Electrical character of bearing

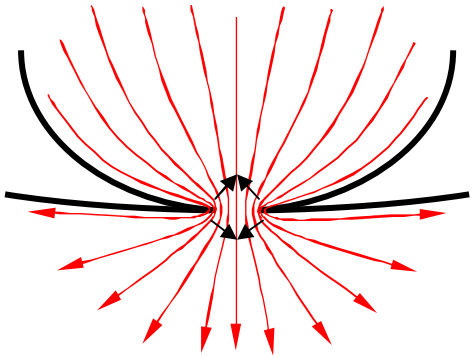

Fig. 2. Curves and compression lines of current in contact spot [1]

4. CAPACITANCE OF PASSAGE AND SPECIFIC DIELECTRIC STRENGHT

In case of correct lubrication of bearing it can be assign theoretical capacitance of oil film i.e. by solve from geometric proportion of contact spot. There is some problem with determination of oil proportional permeability and determination of electrodes average distance in this case contact areas.

Practically, it can be assign capacitance of bearing by measuring with HF source of small voltage or using RLC meter. In both methods there is not measured one passage capacitance but configuration capacitances of all passages in bearing. For example ball bearing 6213 filled by oil U3 rotating by 1000 rpm has the capacitance 1,8nF. The capacitance of bearing 6206, witch is filled oil by producer of the bearing and is rotating by the same rpm is 0,22nF. So that capacitance of bearings is dependent on many parameters and values are balances between wide limits.

In case of correct bearing lubrication there is not possibility to make a conductive contact of rolling bodies. The oil film between the rolling bodies make theoretically a dielectric dividing line witch stop the current passing. Own oil dielectric strength is variable and dependent on oil quality and layer obesity. Oil dielectric strength is often described by break-down voltage witch is between 0,4V to 5V. In next chapter is described experiment with some bearings filled by various oil kinds. It was monitored the dependence of break-down voltage on temperature of this bearings too.

5. EXPERIMENTAL VERIFICATION OF INSULATIVE BEARINGS CHARACTERS DEPENDING ON USED LUBRICANT

Bearings 6206 were filled by chosen lubricants and placed on the shaft of the 3phases induction motor 0,4kW, 2p=4. The outer ring of the bearing was fixed. Two metal-graphite brushes were fixed at the socket. These are insulated against to the motor cage. The motor was fixed at the climatic room. The temperature of the surroundings and thus temperature of the bearing is possible to change by using a climatic room. The temperature was measured by thermocouple at the outer ring of the bearing. The dielectric strength was measured by the regulation source 0-20V 50Hz. The voltage of source is brought to the outer ring of the tested bearing and to the bearings parallel connected. The restrictive resistance 33Ω is connected to the circuit too.

The standard lubricant was cut off from bearings at first. Bearing were filled in the same amount of the chosen lubricant at next. The amount of the lubricant was defined so that lubricant filled 50% area among roller elements. Bearings were clothed by rubber dusters after filling.

The in-running of bearing was passed after bearing mounting on the socket during the time of 1 hour. The self testing was realized after the mentioned period 1 hour, individual's tests were proceeding for the temperature increasing. When the temperature was adjusted, the AC voltage was applied to the tested bearing. The amplitude of AC voltage was increased from 0 to 20V. Courses of instantaneous values of voltage and current by bearing were recorded by the oscilloscope (See Fig. 3). It is evident, that disruptive discharges of bearings exist for the definite voltage. The current begins run through the circuit for conductive connection of bearing rings. The record was saved for the individual temperature and temperature at climatic room was increased after record's storage.

Tab. 1. Tested lubricants

Lubricant	*Lubricant base*	*Range of temperature (°C)*	*Point of consistence NLGI*	*Viscosity for 40°C*	*Notice*
Common lubricant					Lubricant of bearing's producer
U3	lithné	-40 ÷ +120	2	107	For high-temperature running
K2	microgel	-40 ÷ +180	2	100	Synthetic oil
S3	lithné	-30 ÷ +130	3	100	
M	lithné	-40 ÷ +180	2	95	Acceptable for electromotor
S2	microgel	-65 ÷ +205	2	30,5	Synthetic oil
N50	metal	-15 ÷ +200	paste		For high-temperature running, contents metal elements

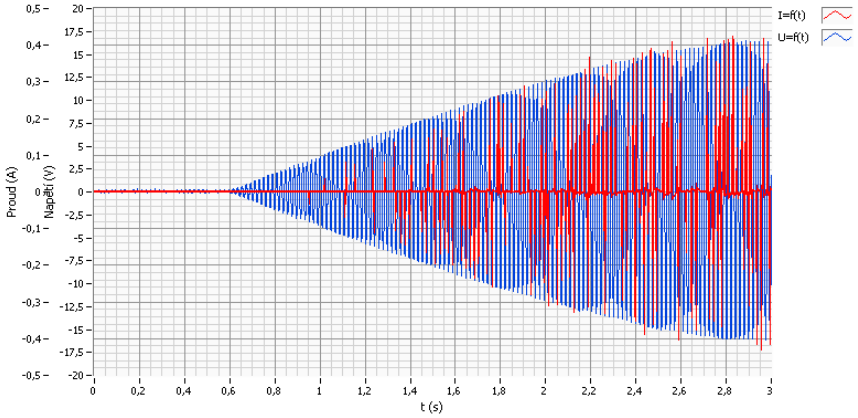

Fig. 3. Courses of voltage and current by bearing for the lubricant U3 62,5°C

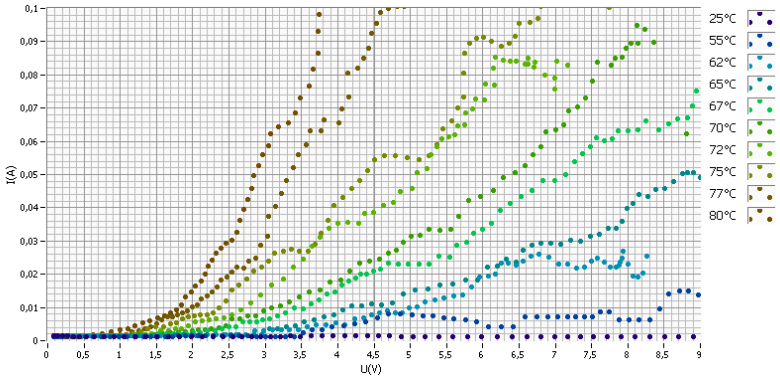

Fig. 4. The example of VA bearing's characteristic with the lubricant U3

The identical test was realized with the applied voltage after temperature standstill, whereas the velocity of voltage modification is identical. The identical test was realized with defined time step up to the 90°C.

The effective value of the voltage and the current course was calculated by the sequential integration. Voltage and current courses are shown at the constant temperature in Fig. 4. VA characteristics bearing pregnant with lubricant and rotating by 1450 min^{-1} are shown in principle in the Fig. 4. The parameter of the VA characteristic is temperature. It is evident, that the value of breakdown voltage is decreased if the temperature is increased.

The effective value of voltage, if the effective value of current by circuit is 10mA, was used as an acceptable parameter. Courses of voltages versus temperatures for some lubricants are introduced in the Fig. 5.

The best specific dielectric strength has bearing pregnant with the plastic lubricant U3, that it is evident from Fig. 5. The specific dielectric strength of rotating bearing is taller by 20V at temperature 40°C.

On the contrary, the bearing pregnant with the lubricant with a metal elements contents is electric conductive also for low value of a temperature. This type of bearing is seen as a resistive element. Transient phenomena are caused by disruptive discharges in the electric circuit. The value current is then influenced by circuit parameters. The effective value of voltage, if the effective value of current by circuit is 10*mA*, it is not only character of bearing, but character of the whole circuit. The parameter of the voltage can be use for the comparison, because all bearing with lubricants were connected to the identical electric circuit. .

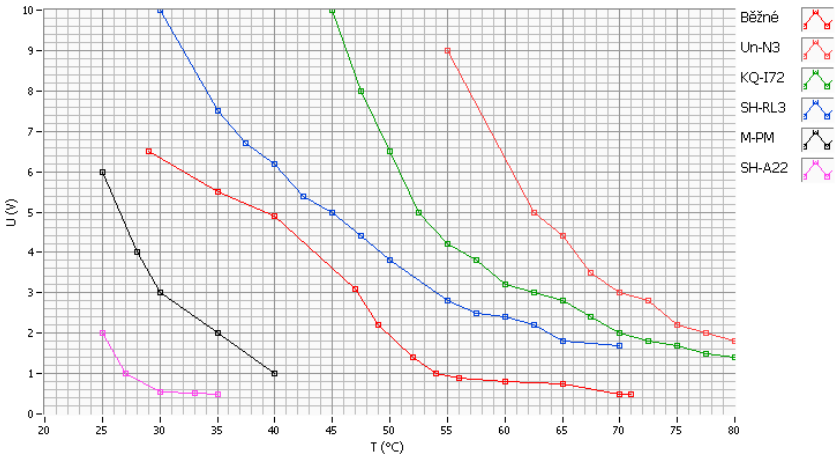

Fig. 5. $U_{10mA}=f(T)$ for variety kind of lubricants

6. CONCLUSION

The bearing current origin, its size and effect is i.e. affected by specific dielectric strength of bearing. A dielectric strength of the bearing is dependent by electrical character of the oil and by layer obesity of the oil. Layer of oil film is dependent on rpm of bearing, viscosity and temperature of oil. The specific dielectric strength rotating bearing is dramatically differs from kind and temperature of the oil. The bearing oil must fulfill many conditions and it is elected by many criterions. Because use of correct oil kind may in specific cases void of negative bearing current creation. The volition of oil kind should make provision for dependence dielectric strength of oil film on temperature.

Acknowledgement

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[1] Pospišilík, J.: *Conditions of shaft voltage and bearing currents origination by non-sinusoidal feeding of electric machine*, Dissertation thesis, Ostrava 2004.