5th INTERNATIONAL MEETING OF THE CARPATHIAN REGION SPECIALISTS IN THE FIELD OF GEARS

ELECTRICAL PROPERTIES-FUNCTIONING TEMPERATURE CORRELATIONS FOR ROLLING BEARINGS GREASES UNDER THE INFLUENCE OF THE ELECTRIC FIELDS

Mihai Tiron, "Gh. Asachi"Technical University of Iasi, Romania
Mihai Gafitanu, "Gh. Asachi"Technical University of Iasi, Romania
Flavian Farcas, "Gh. Asachi"Technical University of Iasi, Romania
Marius Alexandrescu, North University of Baia Mare, Romania

Abstract. *The recent tendencies in considering the electrical motor drives as an alternative ecological power source determined new researches in order to improve their components performances, among them being the rotors rolling bearings. Because of the specific functioning conditions (the presence of the electric/magnetic fields) of their rolling bearings, particular deterioration mechanisms are developed and it was concluded that their service life is strongly dependent on lubricating greases behaviour. This is the reason for which researches in lubricating greases field were ran and they highlighted that their resistivity increases with time under the influence of the electrical fields. Unfortunately the rolling bearings parameters (i.e. temperature) were not taken into account so it was considered justified to develop a researching programme that has as main aim to elaborate a greases deterioration model considering the influence of the electrical fields. The paper presents the first step of this research and it is focused on bearings temperature influence on greases main properties that will be taken into account in establishing the lubricants deterioration model in this specific running conditions.*

Key words: *lubricating greases, electric field, resistivity*

1. INTRODUCTION

The last years tendencies in rolling bearings lubrication research field those who are focused on greases behaviour can be highlighted. This is mainly due to the simplicity of the grease lubrication systems (no cooling or recirculation circuits are needed) and also because of creating new possibilities in miniaturising bearings housings. The more intense presence of greases on world lubricants market and the higher demands concerning the machines or devices performances determined new researches that were focused on greases quality improvement. In this context, remarkable results were obtained in the lubricating greases rheology [1-5], in greases service life considering rolling bearings running parameters [6-8] and, recently, in the environment's influence on greased rolling bearings behaviour [9-10]. In spite of these, the proposed greases service life models have a limited technical applicability because of the insufficient considered parameters, the most reliable of them being that proposed by Gafitanu [6]. The last decade accent on environment's protection also determined the research focusing on electrical drive motors components performances improvement, among these the rotor rolling bearings being an important component. Particularly, they are functioning in specific "electric media" that has an apart influence on lubricants behaviour and properties [9, 10].

Having in view the insufficient approach of the phenomena occurring in the electrical motor drives rolling bearings functioning under the electrical fields it can be concluded that new researches must rolled on in order to have a more complete image about lubricating greases behaviour in such conditions. Having as final long term purpose to elaborate a deterioration model for lubricating greases under the influence of the electrical fields, the present paper presents a first necessary step that intents to establish the correlation that exists between rolling bearings running temperature and greases main electrical properties: its resistivity and capacitance.

2. THEORETICAL BACKGROUND

Typical phenomena were observed in the electrical motors drives rolling bearings and they were put in connection with the specific environment conditions that are present in this situation [11-12]. Potential drops between rotors shaft ends, rotors bearings and bearings housings were identified, an electrical current passing through the rolling bearings. The main causes of this phenomenon are: asymmetries and assembling errors, mechanical unbalances, the un-uniform air gap, accidental applied voltages, magnetising of the rotors shaft or of the other components. The specific failures that appear are due to lubricants deterioration that is subjected to an electro-chemical process (silent discharges) or due to electrical arching

Fig. 1. *Inner ring*

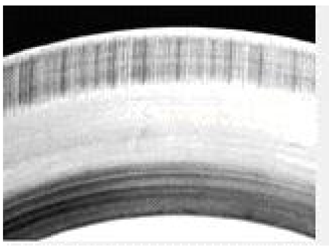

Fig. 2. *Thrust bearing ring*

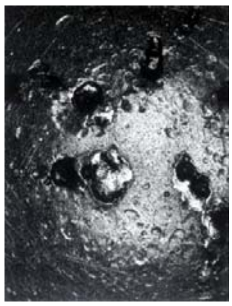

Fig. 3. *rolling bearing ball*

between contact surfaces. The specific damages (figures 1, 2 and 3) are like corrugated pattern, corrosion spots or micro-craters both on raceways and rolling elements [10-12].

Bearings deterioration is strongly dependant on greases behaviour, two situations being evidenced as follows.

a. *Low resistivity greases (< 10^7 Ω cm):* silent discharges occur in the Hertzian contacts that are passed by the electrical current, the raceways surfaces being heated and tempered. The lubricant is chemically decomposed, new corrosive reaction products are obtained such as Li hydroxide and carbonic acid, the corrugation/corrosive spots initiation and evolution is accelerated.

b. *High resistivity greases(> 10^{11} Ω cm):*static electrical energy is accumulated on contact surfaces until a critical level is touched when electrical arching occurs. The failure appears by mass transfer between bearings metallic surfaces to lubricants body and by temperature increasing that determines lubricant's degradation.

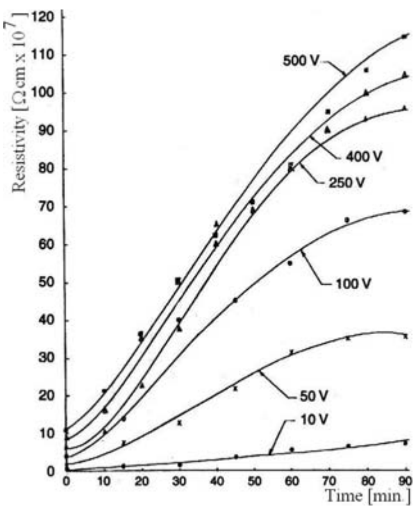

***Fig. 4**. Greases resistivity vs. time*

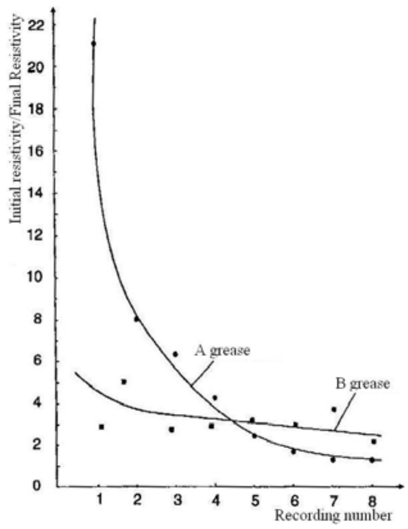

***Fig. 5**. Comparison between breases*

From both situations it can be observed that the lubricant is a very important piece of this assembly, its properties having a significant influence on bearings service life.

The experimental investigations that were ran until present [13] showed that lubricants resistivity increase with time and they have higher values for greater applied potential drops (figure 4). It was also observed that after disconnecting the applied voltage, for two tested greases A and B, lubricants resistivity trends to come back to their initial value but it never succeeded to reach the "0 time" experimental value. The resistivity increase was about 2.35 times for the high resistivity grease B and about 23 times for the low resistivity grease A (figure 5). This behaviour is explained by the fact that grease A has a greater tendency for breaking its molecular chains while the second one has a molecular structure more stable and elastic.

From the above presented aspects it can be observed that no experimental investigation considered temperature's influence on lubricants resistivity which is an important parameter concerning the rolling bearings that are passed by electrical currents.

Based on this information it can be assumed that greases resistivity could be dependant on environment's temperature and have a similar behaviour as material materials expressed by the well known ecuation (eq. 1).

$$\rho = \rho_0 (1 + \theta \cdot T) \qquad (1)$$

where: ρ- lubricant's resistivity at the testing temperature, ρ_0- lubricant's resistivity at 20^0C, θ- temperature-resistivity coefficient.

Having no information about greases electrical properties vs. temperature a simple equation is proposed (eq. 2) in order to reflect lubricant's electrical behaviour when temperature increases.

$$\rho = a + b \cdot T^c \qquad (2)$$

where a, b and c are grease constant dependent.

By numerical experimental data processing the appropriate constant values is expected to be found. Also because of the lack of information about greases dielectric constant, parallel with resistivity measures, experimental estimations for electrical property will be done too.

3. EXPERIMENTAL DEVICES AND ACQUISITION CHAINS

Lubricant's resistivity can be calculated using eq. 3.

$$\rho = (R \cdot \pi \cdot d^2)/(4 \cdot l) \qquad (3)$$

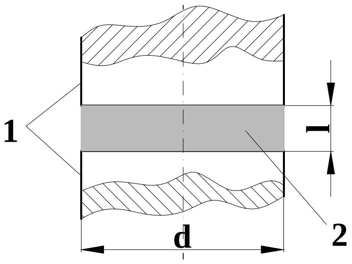

Fig. 6. Test device sketch

where: l- the gap between the electrodes, d- diameter of the electrodes, R- measured electrical resistance (fig. 6).

Considering the same geometry, greases dielectric constant can be determined using equation 4.

$$\varepsilon = (4 \cdot C \cdot l)/(\pi \cdot d^2) \qquad (4)$$

where: ε- grease dielectric constant, C- the measured electrical capacitance. For the experimental investigations four wide use Lithium based and mineral oil greases were selected.

The entire device was put inside a heated shell whose temperature was measured and controlled with a National Instruments automation & measuring system consisting of a J type thermocouple, a NI 5B37 thermocouple conditioning module, a NI DAQ 6024 E data acquisition board and LabView 6.1 virtual instrument software. The sample grease layer resistance from the plane condensers gap was measured using a digital AVO BM11D megohmmetter provided with a PC interface. The scheme of the measuring system is presented in figure 7.

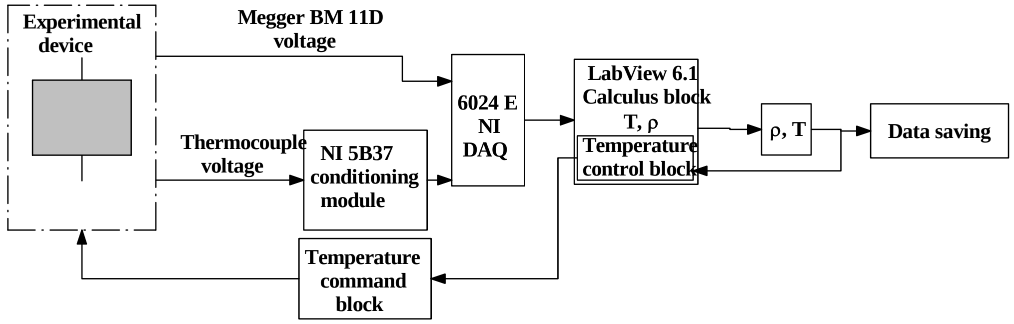

Fig. 7. *Data aquisition chain*

Data acquisition was realised using a virtual instrument able to simultaneously collect data from two channels, calculate the grease sample resistivity with eq. 3 and finally save the data in files for the future processing.

As mentioned above, also an experimental grease dielectric constant-temperature correlation was in view to be established. This step was accomplished with a RCL 0704 bridge that was used to measure greases layer electrical capacitance on whose basis, using eq. 4, the sample grease dielectric constant was also calculated. All test were done for temperatures between 40 and 120^{0}C.

4. RESULTS

The collected experimental data were numerical processed with LabView 6.1, Mathcad 2001i and TableCurve 1.10. The experimental interpolated curves are presented in figures 9 and 10 for greases samples resistivity and dielectric constant respectively. A synthesis of the processed data and the coefficients of the approximation traces are presented in table 1.

Table 1. *Approximation equation and experimental coefficients*

Lubricant	Equation	a	b	r^2	$\frac{\rho_{20^0}}{\rho_{120^0}}$
A	$\rho = a + b \cdot T^{-2}$	$-7{,}2810049 \cdot 10^9$	$1{,}5528384 \cdot 10^{14}$	0,97	108
B		$-7{,}536999 \cdot 10^{11}$	$1{,}4484901 \cdot 10^{16}$	0,91	140
C		$-1{,}9245545 \cdot 10^{11}$	$3{,}3929457 \cdot 10^{15}$	0,94	192
D		$-2{,}9044694 \cdot 10^{12}$	$5{,}3200674 \cdot 10^{16}$	0,94	164

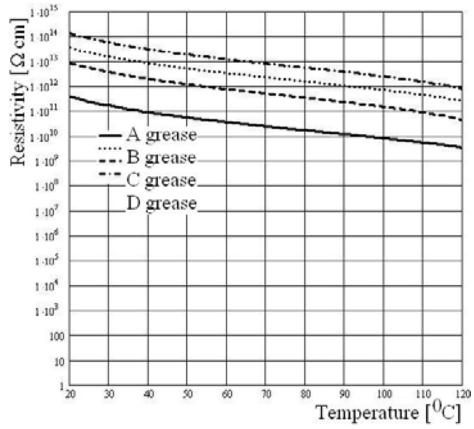

Fig. 9. *Greases resistivity vs. temperature*

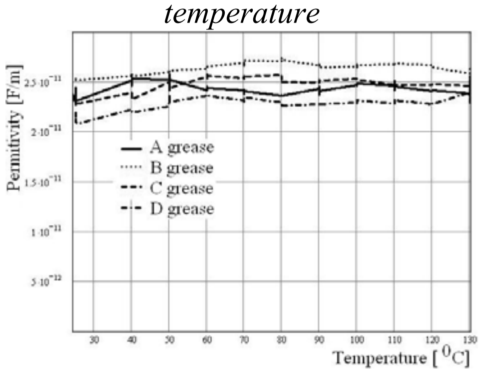

Fig. 10. *Greases dielectric constant vs. temperature*

From the experimental curves (figure 9) and table 2 it can be observed the strong temperature influence on greases resistivity that decreases with temperature rise. Concerning lubricants dielectric constants the experimental data (figure 10) showed that this electrical property is not influenced by temperature in the experiment's limits and for this reason it can be considered as grease electrical constant in future researches.

5. CONCLUSIONS

a. The researches on rolling bearings lubricating greases service life under the influence of the electric fields must take into account bearings functioning temperature.

b. It is confirmed that bearings functioning temperature has a strong influence on greases electrical resistivity.

c. Greases dielectric constant is not dependent on temperature and it can be considered as a material constant in the future researches.

d. By correlating greases electrical properties with service life tests and specific analysis such as the chemical and structural ones, future useful recommendations for choosing the electrical motors drives rolling bearings greases could be formulated.

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