Serbian Tribology Society

SERBIATRIB '15

14th International Conference on Tribology

University of Belgrade, Faculty of Mechanical Engineering

Belgrade, Serbia, 13 – 15 May 2015

THE CONTROL OF THE LUBRICANT FILM BY THE RESISTIVE METHOD FOR SCUFFING

Michaela FOMIN VASILACHE[1,*], Ilie MUSCA[1]
[1]Department of Mechanics and Technologies, University Stefan cel Mare, Suceava, Romania
*Corresponding author: fomin_michaela@yahoo.com

Abstract: *The existence of a continuous film of lubricant increases the electrical resistance of the contact that can provide information on the quality of contact's lubrication. This paper presents some experimental results obtained in the control of the lubricant film presence through the resistive method, in lubricated sliding contact between a spherical roller and a cylindrical disc, with the interpretation which gives indications about the time of scuffing.*

Keywords: *film lubricant, electrical resistance, contact, scuffing.*

1. GENERALITIES

The resistive method, accepted as the most used method in the evaluation of the lubricant film [1], is based on the evaluation of the contact electrical resistance, determined by the existence of a lubricant film that separates the surfaces. The decrease of the film thickness until interruption shall result in the appearance of direct contact and consequently, the decreasing of the electrical resistance value until annulment, when the film disappears. Highly efficient, the method is also used in the evaluation of rough surfaces contacts or occurrence of the micro-contacts. Originally used in 1952 by Lane and Hughes [2] and applied to gear, the method was undertaken and perfected, being extremely effective in monitoring continuous film lubricant presence.

The resistive method has been used before by Lee and Ludema [3], in the study of the lubricated contacts involving roughness, load and speed. In the conducted study they proposed analyzing a less observed situation, namely the time importance as a factor in scuffing and the study of changes that occur in the roughness of the contact surfaces, by pursuing the lubricated contact. Using the resistive method, it was observed the existence of the metallic contact, by measuring the contact resistance values. In order to calculate the load and speed, the EHD equations were used in determining the film thickness between a flat plate and a cylinder.

The obtained results, in terms of using the method for measuring lubricant film by the resistive method, reveal that this method is very accurate in the study of the film presence, providing information not only about the existence or non-existence of a continuous film but also the influence of the used lubricant's quality.

2. CONTRIBUTIONS

The test rig was specifically designed for the study of scuffing occurrence [4], and it uses the resistive method to detect the decrease of the film thickness until its annulment. The presence of the lubricant film in the contact was monitored by using the circuit shown in Figure 1a. The lubricated contact (Fig. 1b) is composed of a cylindrical disk and a spherical roller.

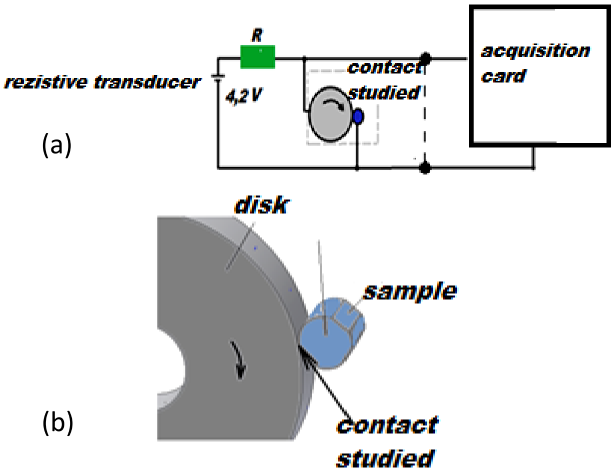

Figure 1. The principle of the contact resistivity control: (a) electrical circuit and (b) contact studied

The electrical connections are attached to the shaft of the electrical motor and to the spherical roller, respectively. The existence of the film and hence its resistance causes a voltage drop, in correlation with its resistance, recorded by the data acquisition system.

Knowing that a resistance inserted into an electric circuit let flow an electric current with an intensity proportional to the voltage applied to them, for the lubricated contact the Ohm's law can be written as:

$$I = \frac{u}{r}, \tag{1}$$

where: I is the current intensity, u is the voltage drop (this being the recorded and tracked value) and r is the resistance of the contact.

For the entire circuit:

$$I = \frac{e}{R+r}, \tag{2}$$

where e is the voltage of the source (with the value of 4.2 V, DC) and R is an additional resistance, introduced into the circuit in order to protect the source to be short circuited, when the direct contact occurs.

The calculation for the film resistance r, appears as:

$$r = \frac{uR}{e+u}. \tag{3}$$

For this experiment it is sufficient a qualitative assessment of the film. The absence of a continuous film implies zero resistance, so the contact voltage drop is null.

The presence of the film implies a non-zero resistance of the contact and a non-zero voltage difference.

For a very thick film or air separation which is equivalent to an open circuit through the contact, the recorded value is equal to the voltage drop across the resistance R.

Besides monitoring the contact voltage drop, the stand also allows the monitoring of other parameters such as the friction in the contact, contact load and relative speed of the disk.

3. RESULTS

The tests were carried out using three types of lubricant: a non-additivated mineral oil, a mineral base oil of a SAE 10 lubricant (additive-free) and glycerin. The tests monitored the contact's electrical resistance parameter value concomitantly to the friction between the roller and the disc load in the contact and the relative speed. Knowing that the presence of the lubricant film excludes direct asperity contact, voltage drops were recorded. The experiment identifies the moment of drastic voltage decline through the contact, in correlation with the values of other monitored parameters in the moment of scuffing initiation.

Monitoring graphs were elaborated for the friction in the contact, correlated with the evolution of the contact resistance (Figs 2a, 2b and 2c).

The contact voltage drop evolution graph (Fig. 2) must be interpreted in conjunction with the working stages. There are four stages of evolution, correlated to the stand's functioning:

1. Before starting the test of lubricated sliding friction control, the roller and the disk are kept at a large distance, this distance being reduced when the speed

of the disk has a large enough value so as to generate a lubricating film (about 1000 rpm);

2. After contact, the elements are pressed one against the other with a constant force;
3. The progressive increase in disk speed until scuffing is initiated, correlated with the destruction of the lubricant film and the contact friction increase;
4. Avalanche onset of the scuffing phenomenon.

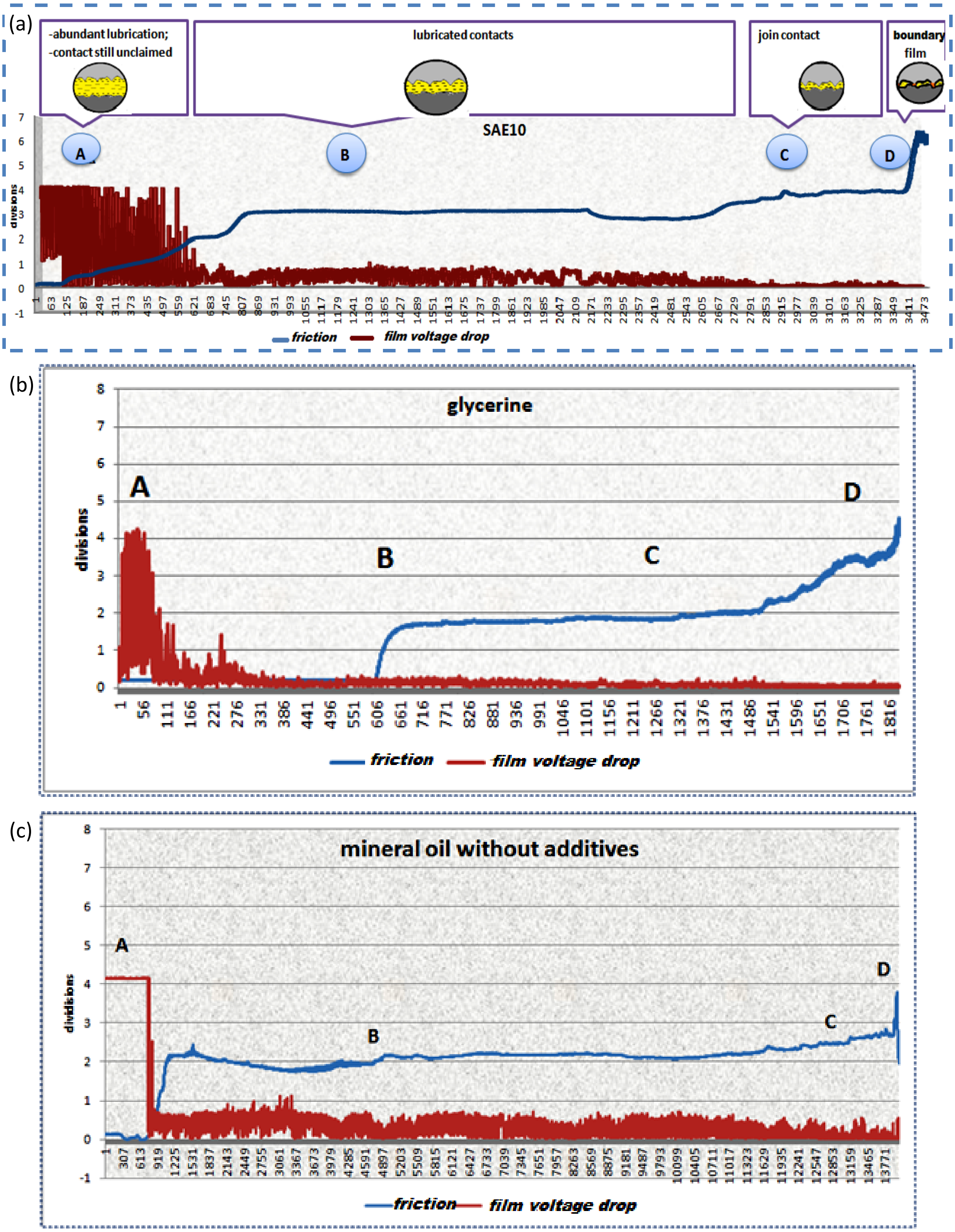

Figure 2. Graph evolution of the voltage value through the contact and contact friction parameter for three different lubricants

The presences of the lubricant film correlated with these stages and with the voltage drop across the contact causes these areas on the diagram in figure:

A: The area where the contact is not yet realized (to protect the surfaces against a premature wear) and the presence of abundant lubrication film which resulted in a signal value equal to the voltage of the battery and the resistance of the contact is practically infinite, corresponding to a zero drop voltage.

B: The area where the contact is realized, when the contact voltage decrease is lower than the voltage of the battery, reflecting the presence of a fluid lubricated film. For this zone, non-zero values of the contact voltage drop can be noticed.

C: The area where the contact voltage drop decreases in correlation with the increase of friction. More zero contact voltage values occur, reflecting micro contacts presence. This evolution can be explained by the friction increase.

D: The limit friction area when the contact voltage drop is reduced suddenly very much close to zero value, correlated with sudden rise of the friction, suggesting scuffing initiation. The decreasing of the recorded signal until annulment when decreasing film thickness occurs is obviously visible on the graph.

In all performed experiments, the time of sudden increase in friction in contact coincides with the sudden decrease of the film resistance, which may provide an indication of the occurrence of direct contact between the surfaces roughness. After this point, it is impossible to continue the experiment because rapid increasing friction values occur, indicating a regime of dry friction and scuffing start. This moment can be the moment of loss of normal capacity to work and the evolution towards scuffing.

4. CONCLUSIONS

Control of the contact resistance, in terms of associated voltage drop is a practical solution of monitoring the presence of lubricant film in contact.

Overall analysis of the acquired data, clearly highlight the working stages during the experiment.

No significant phenomenological differences have been reported from one lubricant to the other.

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