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EXPERIMENTAL THERMAL STUDY OF CONTACT WITH THIRD BODY

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ABSTRACT

The thermal study of sliding contact is complex due to numerous physical aspects highly coupled. Heat generation mechanisms are still badly known due to the complex interactions between mechanical, thermal and physico-chemical behaviours and surface degradations.

In the goal to better appreciate the third body role on the thermal aspect, an experimental set-up has been realized. It consists in two rings sliding to each other, the first one is made of sapphire (rotating ring) and the second one is made of steel (fixed ring). The temperatures are obtained by an infrared camera scanning through the sapphire and by thermocouples on the contact surface specially realized for this experimental set-up. The contact surfaces of the two rings have been observed with a scanning electronic microscope. Comparison between the thermal scene and the surface observations has allowed connecting the third body accumulation with local surface heating.

INTRODUCTION

The study of dry friction between rubbing surfaces is generally closely related to the debris behavior of the interface. The debris particles have often been considered as worn particles from the contact area. The concept of third body was introduced in tribology by M. Godet [1] in order to define physically the components of a friction system and the mechanical interaction between them.

Numerous experimental observations emphasized the complexity of the existing mechanisms in a sliding contact (third body distinction in granular form and in sheet micro-plates, third body flows, etc.) [1,2]. Many observations showed that the accommodation of relative speeds takes place by degradations of the contact surface, by cracks and by superficial tribological transformations (STT) at a depth ranging from a nanometer to several micrometers [3]. It appears that these STT are real material flows parallel to the contact surface. The STT result from very highly local pressure, temperature and contact surface shearing [4]. Few studies have been devoted to examine the interaction between heat generation and third body generation. It can be explained by the experiment difficulty to observe the third body formation and the temperature distribution during the sliding contact [5].

The goal of this study is to give some relationships between third body and thermal field. With a specific experimental set-up and thermal adapted instrumentation, a temperature map of the friction surface is investigated. The third body is observed after contact opening by scanning electronic microscope (SEM). Comparison between theses observations gives indications about the real contact surface and about the heat generation areas.

EXPERIMENTAL SET-UP

The experimental set-up is made of two rings. The first one is made of sapphire and rotates around its axle. The sapphire has been chosen according to its infrared transparency. The second ring is made of C35 steel. It is fixed in rotation and free in translation. Loading is applied on this ring. In order to obtain an axial heat flow into the rings, two thermal organic fibres insulators are fixed inside and outside the rings.

The experimental set-up involves couple and force measurements. The contact surface temperatures are obtained with thermocouples and with an infrared camera. Thermocouples are located on the contact surface of the steel ring. The infrared camera measures the heat radiation of the frictional contact surface through the sapphire ring [6].

EXPERIMENTAL RESULTS

Infrared measurements show that heating zones are very reduced compared to apparent contact surface. Three types of infrared thermograph may be distinguished according to the shape and the movement of the heating areas:

- Fixed areas. Such phenomenon is the main observed during the experiments. These fixed heating zones are associated to the steel ring.

- Moving areas (associated to the sapphire contact surface). Usually, the area shape is more elongated than for the fixed areas and the temperature increasing is lower.

- Moving areas with low speed (associated to a third body flow). During some sequences, one can see low angular displacements of the heating zones, generally not at the beginning but after a period of fixed heating. Successive thermographs show discontinuous variations of these heating movements that may correspond to third body flows.

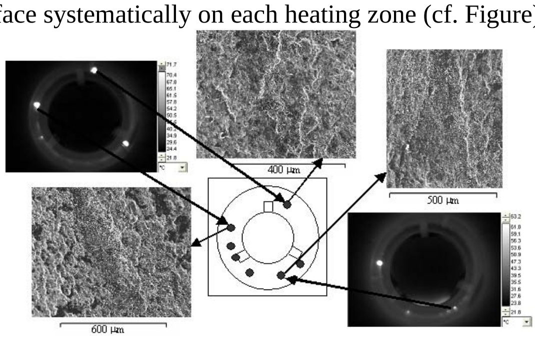
Macroscopic observations (by SEM) show that the steel and sapphire contact surfaces are highly damaged. Numerous traces are observed on the steel contact surface caused by an important ploughing. The contact severity is also visible on the sapphire contact surface by V oriented cracks centred on the mean contact radius.

Two third body types can be distinguished. The first one is compact and smooth as a micro-plate where the contact is localized. The second one is granular. It seems that the granular third body accumulates in hollows to form the micro-plates. Such a scenario may be detailed as follow:

- the contact between two irregular surfaces induces wear particles corresponding to the granular third body which accumulates against geometric irregularities,
- the third body accumulation induces localized contact area with increasing pressure and temperature. Such conditions modify the density of the third body to form a micro-plate,
- if loading conditions become too high, there is fragmentations of the micro-plate and hollows or valleys creation.

CORRELATION BETWEEN SEM AND THERMOGRAM

During tests with high loading conditions, heating zones are concentrated. They are quasi-systematically fixed. Thermographs show that theses zones appear systematically at the same place and that they are fixed during numerous revolutions. Transcription of these heating areas on a scheme and comparison with the steel surface observations show a correlation between the heating areas and the hollows observed. Micrographs show that holes have been developed at the steel ring surface systematically on each heating zone (cf. Figure).



One deduces that the hollows on the steel surface are the main contact sites. During the tests, third body accumulates on surface non uniformities to form compact zones that create contacts. Heat is then generated on very small areas which explains the highly temperatures reached during the tests. Due to the thermal dilatation, the contact zones are distorted and concentrate more and more the contact. This phenomenon is well known as thermo mechanical coupling. As pressure and shearing increase on the distorted zones, wear is concentrated on the top. During the following sequences, contact is generally localized again on the distorted zones, but after several sequences, wear is high enough to induce a hollow on the steel surfaces after cooling. Third body may accumulate again, generally after several rounds to create a new contact.

CONCLUSION

An original experimental set-up has been proposed here, made of two co-axial rings in contact with one of them in sapphire that is transparent to infrared radiations.

The observations of the surface have been made after contact opening at the end of the tests. They have been compared with the infrared thermographs of the latest sequences. The full history of the solicitations, clearly visible on the thermal scenes by the summary of the heating zones, essentially fixed, has even been recovered on SEM analysis.

These SEM observations have confirmed the third body accumulation. The scenario of wear particles compacted as micro-plates where the contact acts seems to be confirmed. Correlations with thermograms have shown that the heating zones correspond to hollows on the steel surface and a scenario of their creation has been proposed.

These experiments seem to confirm the reliability of numerical models describing a thermal surface gradient and thermo mechanical concentration of the contact in privileged zones. It would be helpful to model the experimental set-up to analyze the scenario proposed here. Additional investigations may be done to characterize the interfacial thermal barrier specially the third body thickness and its conductivity.

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