Relating the morphological description of the third body to its rheological behaviour

Relier les descripteurs morphologiques des particules de troisième corps avec les propriétés rhéologiques du contact

Rabii JAZA[1], Guilhem MOLLON[1], Sylvie DESCARTES[1], Amandine PAQUET[1], Yves BERTHIER[1]

1. *Univ Lyon, LaMCoS, INSA-Lyon, CNRS UMR5259, F-69621, France*

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INTRODUCTION

Tribology, as a direct consumer of the fifth of the world's total energy [1], has an availability problem. We do not have easy methods to solve its problems but we need the opinion of the few experts of the domain. As a solution for this problem, Godet introduced the third body theory [2]. Third body is the intermediary element between the two first bodies that are in contact. Due to its position, it has many different roles[3]: separating the surfaces in contact, transmitting the normal load and accommodating the velocity difference. Many have worked on proving that understand the third body leads to understanding the friction phenomena itself.

However, due to the third body position and of the confinement of the contact, in most of the case it is not possible to get access directly to the third body without opening the contact and separating the two first bodies. Direct in situ measurements of its mechanical properties are out of reach, and typical tribological analysis follows a two-fold approach: (1) during a test, large-scale observation of the third body flow and mechanical measurements of the loading system, and (2) after the test, close observation of the third body with different kinds of microscopes and probes. Consequently, many experts affirm that the key to understand the wear phenomenon is to study the third body particles [4].

The aim of this work is relating the data gathered from the analysis procedure described before of the morphological description of the third body with the rheological properties of the contact that produce it. Building this relationship between the two measurements will help predict one from the other.

METHOD

The chosen strategy for this work is to run our own tribological test (rheological data) and to create third body particles (morphological data). Building the relationship between the rheological measurements and the morphological description are ensured using machine learning algorithms. In order to demonstrate the relevance of such algorithms, we need first to validate their ability to build a robust correspondence in a controlled framework.

The tribological experiments are carried out with a pin-on-disk tribometer. The first bodies will be made from 35NCD16 steel. In addition, several conditions of the tests (rotational velocity, normal load and surrounding gas) are modified in order to gather different third bodies. The morphological measurements are the descriptors of the third body resulting from analysing the post-mortem microscopic images. While the rheological measurements are gathered using force sensors and high-speed cameras.

Relating the two properties together is realized using machine learning algorithms. During this work, different technics are used like linear classification, support vector machine (SVM) and neural networks. The main objective of the algorithms is to find a connection between the rheology of the third body and the associated morphological description. This connection is expected to provide tools for the prediction of the rheological state of a third body just from its morphological parameters.

RESULTS and DISCUSSION

Until now, tribological tests are carried to create different third bodies with the conditions resumed in the table below. At the end of each test, scanning electron microscopy (SEM) was used to gather microscopic images of the third body. A human-machine interface is developed, including algorithms to analyse the post-mortem images, and a database is constructed with the relevant morphological descriptors [5] of the third body particles namely Elongation, Regularity, Roundness and Circularity.

Table 1: The conditions of the tests

Experiment	Test 1	Test 2	Test 3
Humidity	51%	51%	50%
Temperature	21°	21°	19°
Duration	15 min	30 min	60 min
Linear velocity	1.6 m/min	0.66 m/min	0.387 m/min
Normal force	10 N		

From each test, we gathered 30 particles and collected the morphological descriptors using image analysis technics. The mean of all descriptors for each are calculated along with the standard deviations to estimate the homogeneity inside a set itself. Two descriptors are shown in the figure 1. The morphological set combined with the rheological data (judgment on the third body flows, COFs…) are the learning database that the machine-learning algorithms will use to link the two properties.

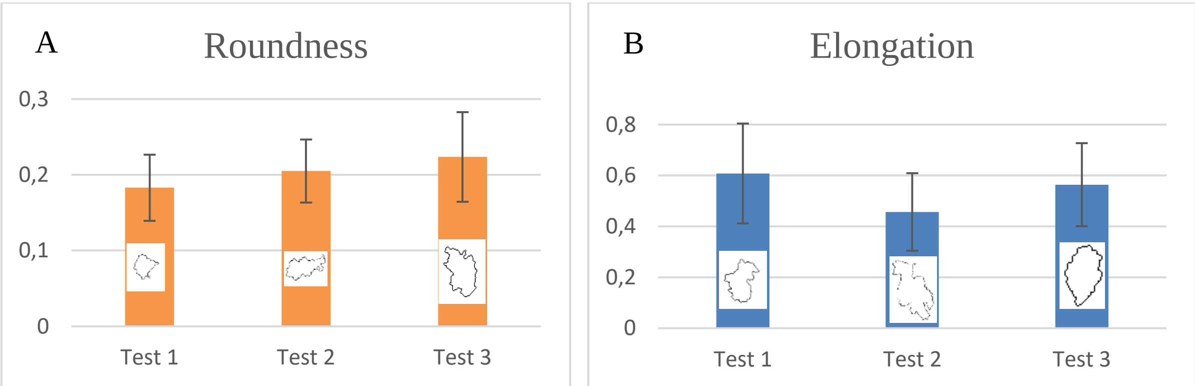

Figure 1: A) Roundness result examples. B) Elongation result examples

The goal is that the machine learning algorithms detect a pattern in both data. Therefor given one property, it can predict the other. Classical steps of training and validation on separate subsets of the database will be performed, and the success ratio in the validation stage will be used as an indicator in order to optimize the parameters of the Machine Learning algorithms. If this experimental stage is successful, it is expected that the chosen algorithm will establish a logical connection between the rheological and morphological measurements.

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