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# FRICITION OF ROUGH SOFT MATTER CONTACTS: LOCAL INVESTIGATIONS THROUGH IMAGE CORRELATION TECHNIQUE

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## INTRODUCTION

The friction induced in contacts is a key feature concerning functionality of mechanisms, reliability of systems, energy consumption... Friction on soft matter occurs in many applications (tire/road contacts, touch-sensitive exploration, micro-manipulation of biological items...) as well as in nature. The latter offers various examples of how a topographic surface pattern may control friction. The result is a complex combination of phenomena: adhesion, elastic ratio of bodies in contact, viscous flow, plasticity occurrence, and topography interaction. The role of this latter phenomenon essentially lies in the splitting of the contact area between the two contacting materials and plays an important role on friction response when coupled with adhesion.

In this context, improving our knowledge on textured adhesive contacts is of prior interest and represents a great scientific challenge since it might lead in the end to acquire the ability to finely tune and control the friction of polymers by texturing their surfaces. Although the wettability properties of textured surfaces have been largely investigated in the past decades (1-2), their mechanical response to a sliding contact remain to be further explored. As precursor works on contacts involving elastomers, one can refer to Roberts (4), Moore (5) and Persson (6) among others. The contributions of different phenomena (viscous flow, adhesion, roughness,...) in the friction response are largely discussed, although several points still need to be elucidated.

Few studies couple in-situ visualization of contact and image correlation in the case of textured adhesive contacts. Actually, image correlation is usually applied to local studies of the behavior of bulk specimen under simple or coupled loading. Since the image correlation technique needs to follow through

time and space a specific marking, it is classic to use calibrated flecks of paintings (8) or techniques of deposition/engraving of micro-grids (9) on an elementary representative surface of the specimen. These traditional methods are obviously not adapted to the local mechanical study in the case of friction tests since marking may not withstand the contact or may perturb the measure itself. Chateauminos et al. studied the behavior of an adhesive material under a torsional contact with the help of image correlation and discussed slippery conditions (10). They followed a regular pattern engraved in the surface of the material. More recently, Tuononen (11) used the image correlation technique in order to study the sliding contact between tire tread blocks and glass. The author identified the local events that are precursors of sliding of the full block. One may note that the correlation directly used the topography of the tire's patterns.

The present approach consists in studying the local contact mechanics of rough elastomeric (PDMS) plane samples while sliding against a glass-made rigid sphere thanks to the image correlation technique. Under specific sliding conditions, some partial stick/slip event may be observed in the inner zone of the contact, and correlated with friction measurements. Thus, the image correlation technique has been used to study the occurrence of this partial stick-slip event. Asperity cooperation and the relevance of several parameters as local stick-slip occurrence indicators are discussed.

## EXPERIMENTAL PROCEDURE

The home-made friction apparatus has been fully described elsewhere (12) and has been modified to be equipped with a built-in microscope which allows in-situ observation of the indenter/sample contact through the spherical tip (see Fig. 1).

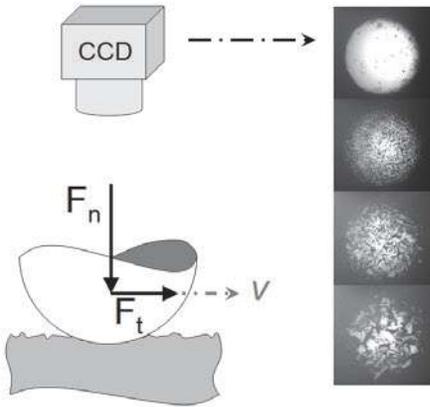


Figure 1: Rough sliding contacts with in-situ observation.

The polymer used was a polydimethylsiloxane (PDMS, Rhodia, Rhodorsil RTV141 A+B), supplied in a two-part kit consisting of liquid components. The base and curing agents were mixed in a weight ratio of 10 parts base to 1 part curing agent with stirring for about 2 min. Cross-linked samples were obtained by molding the mixture on rough metallic surfaces after removing air bubbles by vacuum process. Curing lasted 2 h at 80 °C.

Digital Image Correlation has been performed thanks to a commercial software, IcaSoft (<http://icasoft.insa-lyon.fr>), used in sequential mode.

## RESULTS & DISCUSSION

As reported previously, some stick-slip phenomena occur in the contact area, notably some partial stick-slip restricted to the inner zone depending on test conditions. These instabilities can be clearly identified in the friction signal (not reported here). Further investigations consist in improving these observations with the local exploration of the sliding contact.

In the manner of Tuononen (11), we engaged some image correlation on the test movies (Fig. 2 to 5: full image scale is 1.5 mm large). Fig. 3 shows the strain field in the scratch direction and confirms the expected classic distribution: it points out that the matter undergoes compression while entering into the contact (blue-green) whereas stretching occurs when leaving (purple-black).

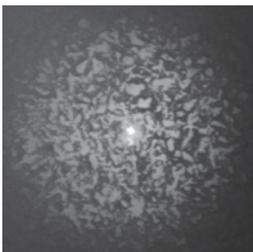


Figure 2: Detail of a sliding rough contact.

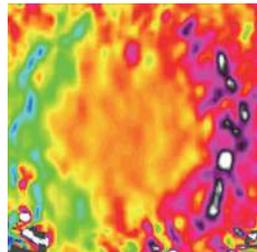


Figure 3: Strain in scratch direction (left to right).

Fig. 4 represents the local rotations calculated thanks to the correlation technique. The inner contact, which remains in a nearly-homogeneous neutral state, is surrounded by a ring-shape. This latter is located right at the contact boundary and shows extreme values (green vs purple:  $\pm 3^\circ$ ) on each side of the contact. This gives information on the flow of the matter that is submitted to shear all around the contact respectively to the scratching direction. Fig. 5 shows the shear angle in the contact and witnesses a fortuitous capture of the stick-slip event: the white arrow points at the slip front that suddenly propagates to the stuck inner zone. Scale has been enhanced in order to highlight this event.

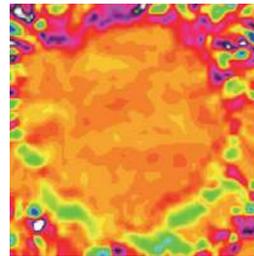


Figure 4: Local rotations inform on matter "flow".

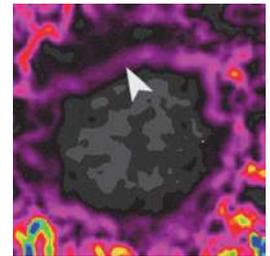


Figure 5: Stick-slip instability highlighted by the shear angle.

## CONCLUSIONS

The aim was to investigate the contact behavior of a rough PDMS surface during sliding against a spherical tip. Partial stick-slip has been observed in a restricted inner zone of the contact. The image correlation technique helped to get insight the local behavior of the matter and pointed out the shear angle and the local rotations as major indicators of these instabilities.

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