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Experiments and analysis of the relationship between bulk mechanical properties, friction and scratching

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Experimental and numerical analyses of the scratch test were carried out for various local friction coefficients and contact strains. A thermoplastic polymer (PMMA) was chosen to investigate the scratch resistance and its relationship to mechanical properties. Thanks to the in situ contact images the mean contact pressure was analysed as a function of the geometrical contact strain and the local friction coefficient. Numerical simulations give some indications as to the location of the boundaries between the different types of contact (elastic, elastoplastic and fully plastic) and confirme that the scratching behaviour is determined by the local friction coefficient and the geometrical contact strain.

Keywords: polymers, scratch, friction, contact strain, FEM.

1. Introduction

The mean contact strain (0.2 a/R) normally used to analyse the scratching does not take into account the local friction between the sliding tip and the surface, especially in the case of polymeric materials for which the friction coefficient may be high.

2. Methods

Experimental set-up: our experimental scratch test, called microvisioscratch has been described in [1]. In the present work a cone-shaped diamond tip with a spherical extremity of 100µm was used and only the spherical part was in contact with the surface. The normal load ranges from 0.1 to 5 N in as many steps as required to explore the entire range of strain sensitivity. At each loading step in situ photographs were taken to record information on the shape of the true contact area.

Surface cleaning: with a good cleaning process high friction surfaces (HF) had an estimated local friction coefficient of about 0.4. Conversely, low friction (LF) samples were not cleaned and had an estimated local friction coefficient of about 0.15.

Estimation of the friction coefficient: an analytical model to determine the apparent friction coefficients of tips scratching a surface was previously presented [2]. If the ratio of the local shear to the local pressure is termed the "local friction coefficient", then the apparent friction coefficient may be written as:

$$\frac{Ft}{Fn}=\mu_{app}=\frac{C+D\mu}{A+B\mu} \tag{1}$$

The integrals A, B, C and D are the local pressure and shear elementary action integrals, taking into account the rear contact angle, the real contact area, the geometry of the tip and the macroscopic contact shape. As the apparent friction coefficient and the shape of the tip are known from experimental data, the local friction may be deduced using the previous equation.

3. Results

Figure 1 shows typical in situ contact areas for the two levels of friction. It is important to note that:

• if the friction is high, the mean contact pressure is greater than when the friction is low, even if the applied normal load and the geometrical contact strain are lower;
• the groove left on the surface is smooth for LF PMMA but may display cracking and crazing for HF PMMA;
• up to a normalized contact pressure of 1.6, for LF PMMA the matter moving with the tip has some difficulty in forming a continuous cord around it, whereas for HF PMMA the matter is very quickly pushed around the tip. Figure 2 shows a plot of the normalized contact pressure versus the geometrical contact strain for the two levels of friction. Assuming that the plateau level corresponds to full yielding of the contact, this representation confirms that the geometrical contact strain and the friction play similar roles in the appearance of a fully plastic contact. Numerical approache using finite element modelling has been challenged by these in-situ observations [3].

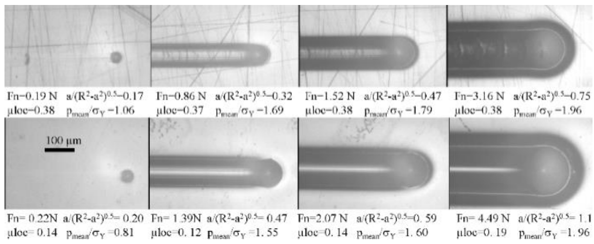

Figure 1: Typical contact areas observed during scratching of HF (top) and LF (bottom) PMMA.

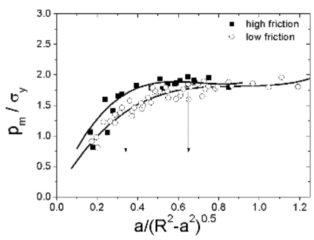

Figure 2: Normalized contact pressure versus geometrical contact strain for HF and LF PMMA

4. References

[1] C Gauthier, S Lafaye, R Schirrer, Tribology International, 2001, 34 (7), 469-479
[2] S Lafaye, C Gauthier, R Schirrer, Tribology International, 2005, 38 (2), 113-127
[3] H Pelletier, C Gauthier, R Schirrer, Tribology Letters, 2008, 32 (2), 109-116