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Friction dynamics at a microscopic level

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Introduction

The velocity dependence of friction is one of the main reasons for stick-slip. When the friction decreases with increasing velocity (velocity weakening), stick-slip can occur. When the friction force increases with velocity (velocity strengthening) stick-slip will not occur. Velocity weakening can be described as a function of contact time, $t_{ce}$, while velocity strengthening can be described as a function of sliding velocity, $v_s$. The velocity dependence of friction severely complicates material selection and is usually ignored. However, precision positioning systems depend on smooth motion and the squeaking and squealing can become so irritating that devices become effectively unusable. This poster demonstrates the use of single-asperity measurements as a means to study stick-slip.

Material and method

Material

Two polystyrene (PS) grades with a narrow molecular weight distribution were used. One with $M_N = 56\, \text{kg/mol}$ and one with $M_N = 1000\, \text{kg/mol}$. A parabolic diamond tip with a radius of $10\, \mu\text{m}$ was used, so that contact diameter $D$ is proportional to the square root of contact area, $A_c$, and indentation, $z \propto A_c$.

Method

Using the LFA [2], a single-asperity friction measurement device that can achieve velocities between $10\, \text{nm/s}$ and $1\, \text{mm/s}$, slide-indent slide experiments were performed (figure 1).

Results

![Graph A](image1)

Figure 2 Measurement of contact geometry as a function of contact time during sliding (A) and during hold at $v_0 = 25\, \mu\text{m/s}$ (B) and at $v_0 = 25\, \text{nm/s}$ to $v_0 = 1\, \text{mm/s}$ on $1000\, \text{kg/mol PS}$ (C). The estimated contact time, $t_{ce}$, is inversely proportional to the $v_s$. $D(t_{ce})$ is independent of $M_N$, while $\Delta z(t_h)$ is dependent on $M_N$. $\Delta z(t_h)$ is strongly dependent on $v_0$.

![Graph B](image2)

Figure 3 A: $F_L$ measured on both PS grades, $F_{max}$ (open symbols) and $F_F$ (closed symbols). The lines are fits with rate- and state equations [1]. B: Shear stress, $\sigma_s$, as function of $v_s$. $56\, \text{kg/mol PS}$ shows no velocity strengthening, while $1000\, \text{kg/mol PS}$ does.

Conclusions

Creep effects could be distinguished from stress effects. This way it could be established that low $M_N$ PS shows a higher shear stress than high $M_N$ PS and does not exhibit velocity strengthening in the velocity range studied. Because velocity strengthening stabilises sliding, low $M_N$ PS is more sensitive to stick-slip.

References: