From single to multi-asperity friction

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R.P. Schaake, W.P. Vellinga, H.E.H. Meijer
Eindhoven University of Technology, Department of Mechanical engineering
TNO Industrial Technology, Surface Engineering

Introduction

Single asperity dynamic friction measurements have proven to be successful in evaluating fundamental aspects of friction of polymers. Still the translation of the results to more practical multi-, or interacting, asperity situations needs to be addressed.

Material and methods

A PS surface was patterned by embossing with an AFM calibration grating. The resulting pattern can be seen from figure 2, The ridges are 1.5 μm, high and 3 μm wide. Friction measurements were performed with a LFA [1], a device designed for quantitative dynamic friction measurements. A fluoridated tungsten tip with a radius of 3.5 μm was mounted on leaf spring units of different stiffness. The effects of a regular roughness pattern and cantilever stiffness were studied.

Results

Measurements on flat and rough surfaces indicated that there were several sliding and deformation modes, these are shown in figure 1. Four different modes can be discerned, steady sliding (I), unstable sliding (II), periodic stick-slip (III), and aperiodic stick-slip (IV). The orange arrows indicate the length of a stick-slip period. On a flat surface mode I, steady sliding, is found.On rough surfaces the sliding mode is dependent on load and driving spring stiffness.

With a weak driving spring mode III, is found, the period of the stick-slip cycle is the same as the period of the surface roughness. Since the stick-slip is caused by the surface geometry, this kind of stick-slip motion is usually referred to as geometric stick-slip. It should be noted, however, that the geometry causing the stick-slip, is that of the surface deformed by the tip-surface interaction. At loads above 1.5 mN the period of the stick-slip doubles, a possible explanation is that the two roughness peaks in contact with the tip now interact with each other.

Using a stiff driving spring, mode II is measured at low loads. With increasing load mode IV is found after a transition through mode III. The transition from single to multi-asperity interaction is expected to lie in mode III.

AFM images show the different deformation that can arise from the use of a different spring stiffness. The plastic deformation at a load of 2 mN shows large differences with a changing leaf spring stiffness.

References:

[1] Hendriks, C.P. and Vellinga, W.P.: Rev. Sci. Instr. 71, 2000, pp. 2391-2402

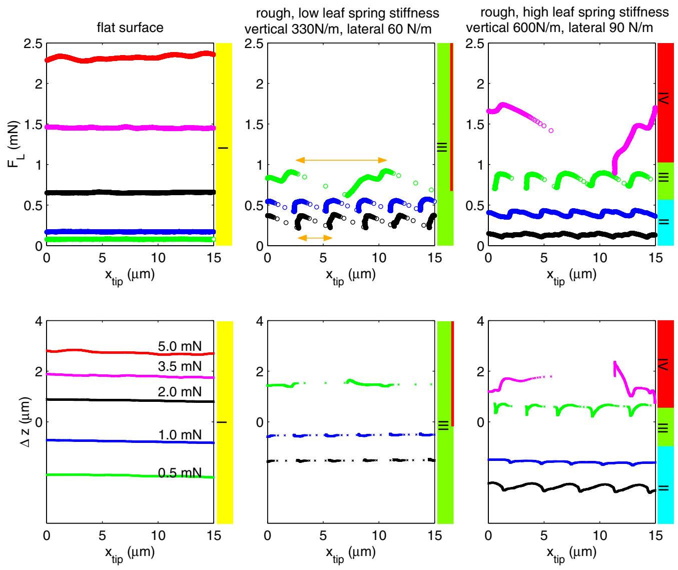

Figure 1 *F_L and Δz (vertical motion) vs. tip position at different normal loads (0.5 - 5.0 mN) on flat (left) and rough (middle and right) PS.*

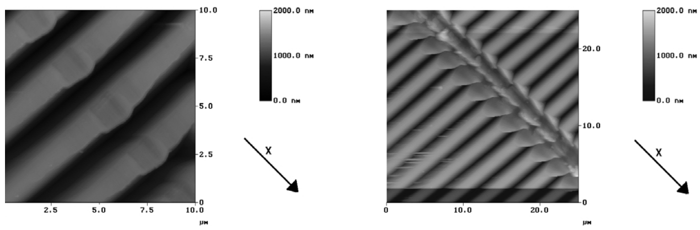

Figure 2 *AFM images of the plastic deformation after LFA measurement at 2 mN normal force with a low (left) and high (right) stiffness leaf spring unit.*

With the introduction of roughness, mode I no longer occurs and averages fail to capture the differences in sliding and deformation modes. This becomes clear from figure 3, in which the average friction levels from figure 1 are shown.

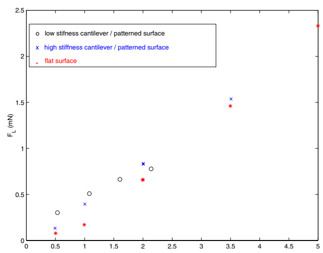

Figure 2 *Average F_L*

Conclusion

Single asperity friction measurements on smooth and rough surfaces show qualitatively differing behaviour, indicating the necessity for a close study of single-asperity sliding on rough polymer surfaces.

PO Box 513, 5600 MB Eindhoven, the Netherlands