How surface roughness influences the real contact area in elastoplastic systems?

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We study elastoplastic contact between solids with self-affine fractal surfaces in different resolutions both experimentally and theoretically. By decreasing the resolution of our contact area measurement and surface profilometry systems or, alternatively, by removing the smallest surface roughness features from the theoretical calculations, we show that the resolution appears in the same way in the real contact area and the root-mean-square (rms) slope of the surface roughness; two quantities that are inversely proportional in the contact mechanics models. However, the measurement resolution dependency problem, in determining the actual contact area in an interfacial phenomenon, is resolved in nature by plastic deformation at the smallest scale asperities.

Keywords: resolution, mean slope, contact area, plastic deformation

1. Introduction

Almost all surfaces are rough on microscopic scales. Rougher surfaces make a smaller area of molecular interaction when they are brought into contact with another surface. In this way, roughness controls many important surface and interface phenomena such as hydrophobicity, friction and adhesion. Simple analytical contact models as well as finite element calculations have shown that the real intermolecular contact area between two rough contacting surfaces is proportional to the normal force that press the surfaces together and inversely proportional to the rms-slope of the surface roughness [1]. But, the latter strongly depends on the resolution of the instrument that is used to measure the surface profile (see the Figure). This problem is addressed by eliminating surface features that are smaller than a given length scale, or equivalently by introducing a cutoff wave vector in Fourier analysis of the surface. We show how in nature plastic deformation at the asperities defines the real contact area uniquely.

2. Methods

2.1. Following experimental methods are employed: pressure-sensitive fluorescence molecules for contact imaging [2], laser scanning microscope for surface topography measurements, and sandblasting for roughening different surfaces.

2.2. We use Fourier analysis and self-affine fractal description of the surface roughness [3].

2.3. The average slope of the surfaces were calculated using the central difference gradient method programmed in Python.

2.4. Finite-element calculation of the area of real contact was performed on the height profile data.

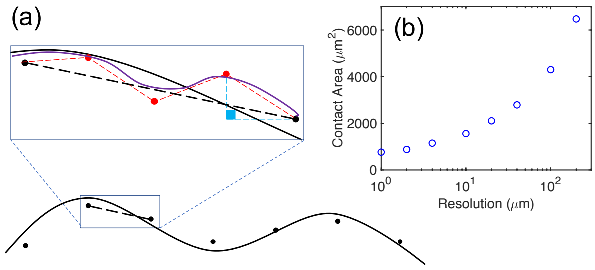

Figure 1: (a) The rms-slope of a rough surface increases with the resolution of the surface measurement. (b) The calculated contact area as a function of the resolution.

3. Discussion

The real contact area, in an entirely elastic contact with a smooth half-space, and the rms-slope for a given self-affine fractal surface are identical functions of the microscopy or calculations resolution. However, the contact pressure between two solids and the related physics phenomena should not have this resolution dependency. In fact, in the real-world contact between solids, plastic deformation at the smallest asperities always defines a limit that under which the instrumental or calculations resolution is not important anymore. Using this natural resolution criterion of the problem, the calculated rms-slope of a surface, which can be resolution-dependent fractal down to atomic scales, can be used to determine the average pressure at contact as a well-defined physics quantity through the contact mechanics models.

4. References

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