The Role of Mechanics and Chemistry in Contact Evolution

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It is known that contacts evolve over time, resulting for example in time-dependent static friction. However, it has been a subject of debate for long time whether such contact ageing comes from an increase in the contact area due to plastic creep or due to enhancement of the shear strength due to chemical bonding. Here, by combining experiments and multi-scale simulations, we bring insights into how much of the evolution of the contacts comes from creep vs. chemical bonding, and how this balance depends on the properties of the interface.

Keywords: contact ageing, creep, chemical bonding, kinetic Monte Carlo simulation

1. Introduction

It is well established that friction depends not on the nominal contact area, but on the real contact area $\sum A_{real}$. The real contact area is much smaller and is comprised of multiple contacting asperities within the nominal contact. The friction force F can be written as $F = \tau \sum A_{real}$, where τ is the shear strength per unit real contact area. Recent experimental [1,2] and simulation [3] studies have revealed that for many material interfaces, the real contact area and the shear strength τ are not constant for a given contact, but instead can have a pronounced time dependence. This time evolution could arise either due to plastic creep that leads to an increase of the contact area (i.e., contact quantity) over time, or due to chemical reactions that change the shear strength (i.e., contact quality) over time. The time evolution of the contacts is referred to as ageing. Among other phenomena, it often results in an increase in the static friction logarithmically with time. Studies of contact ageing have typically focused on one of these two aspects – either creep-induced ageing or chemistry-induced ageing. However, it is likely that both ageing mechanisms play non-negligible roles concurrently in real contacts and it is also possible that the effects of the two mechanisms are coupled to each other.

2. Discussion and Results

In this talk, we will discuss results of our studies on some of the key outstanding questions, i.e., how much of the evolution of the contacts comes from creep vs. chemical bonding, and how this balance depends on the properties of the interface. For example, our simulation results show that even if there is no creep, chemical bonding can lead to an increase in the contact area (not just the shear strength) due to the adhesive force from each individual bond. In other words, chemical ageing can contribute to an increase in both A_{real} and τ over time. The rate of increase in static friction due to chemical bonding is a function of the surface chemistry, contact pressure, and the environment. It can be compared to the rate of creep, which has been obtained from our experiments (Fig. 1) at various contact pressures and for a range of humidities. By combining experiments and multi-scale simulations of both single-asperity and rough multi-asperity surfaces, we provide new insights into the dependence of the dominant ageing mechanisms on sliding conditions.

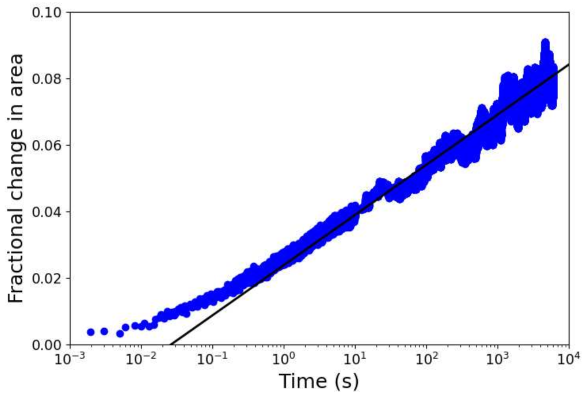

Figure 1: Fractional change in the real contact area vs. contact time. The experiments are done by nanoindentation creep tests on quartz at relative humidity = 25%. Black line is a linear regression fitting to the data points above 0.1 s.

3. References

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