
Impact of friction on adhesion of elastomeric contacts

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Abstract

From industry to biomechanics and basic sciences, adhesion forces have been an object of study for the last decades. These forces are present in most contact interactions and depend strongly on the microscopic properties of the surfaces in contact. A conventional method to measure the energy of adhesion between two surfaces is to measure simultaneously the force and the real contact area during the charge or discharge of a sphere/plane contact and then to evaluate the adhesion energy by applying a relevant adhesive model, for instance the JKR model (1). Here, using smooth contacts between elastomer spheres and rigid plates, we study the evolution of this the pull-off force (adhesion) when the contact is sheared prior to separation.

In our experiments, we have first generated a contact between a semi-sphere of elastomer (PDMS) and a glass plate at a constant normal force. Once the surfaces are in contact, a preliminary shear is performed (with different amplitudes) generating tangential forces smaller than those necessary to trigger the full sliding. Finally, the normal load is reduced until the full separation of the contact. During the process, high precision measurements of the forces (6-axes) and detailed images of the contact area are obtained thanks to the multi-axes opto-mechanical apparatus recently designed in our laboratory (2). In practice, we study the pull-off force, ie the force necessary to fully separate the solids in contact, as a function of the amplitude of the initial shear force.

Our experiments for different normal forces and maximal preliminary tangential forces show that the pull-off force steadily decreases as the preliminary shear increases, as long as the initial shear is lower than about 50 microns (3). For larger shear, we find that the contact reaches full sliding during unloading and thus the pull-off force remains constant, at a residual value 10%–15% of its initial value.

Based on those observations, a first modeling attempt of the critical shear displacement is proposed, involving a competition between jump instability and transition to sliding. Overall, those results offer new insights into the interplay between adhesion and friction, provide new constraints on adhesion measurements and challenge existing adhesive models (4).

Finally, this drastic decrease in pull-off forces could be used as a method to separate surfaces in a possibly more efficient way than simple normal pulling and may be useful wherever soft contacts undergo both normal and shear stresses, including tire grip, soft robotics, haptics and animal locomotion (5).

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