Adhesion evolution on slightly sheared dry elastomeric interfaces.

Cristóbal Oliver[1)*], Davy Dalmas[1)] and Julien Scheibert[1)]

[1)]Laboratory of Tribology and Systems Dynamics, Ecole Centrale de Lyon, France
*Corresponding author: cristobal.oliver@ec-lyon.fr

Adhesion forces are present in most contact interactions and depend strongly on the microscopic properties of the surfaces in contact. In this work we present measurements of the adhesive properties of a contact between a PDMS semi-sphere and a glass plate during normal unloading of a contact submitted to a preliminary shear. Our objective is to decipher the role of shear loading on the evolution of the adhesion. Our results show a significant decrease in the the pull-off force, ie that necessary to fully separate the solids in contact, even for small initial shears on the order of a few microns. We will discuss the effects of this shear on the adhesion energy and possible models that describe the situation.

Keywords: tribology, adhesion, contact mechanics, elastomer

1.Introduction

From industry to biomechanics and basic sciences, the adhesion force has been an object of study for the last decades. This attractive force appears in the contact between two surfaces and its responsible, for example, that geckos and some insects can walk on walls and ceilings, even on smooth surfaces such as glass. In this work, we aim at showing the effects of an initial tangential force on the adhesion forces in a smooth and dry contact.

2.Methods

A conventional method to measure the energy of adhesion between two surfaces is to measure simultaneously the force and the real contact area during a contact charge or discharge and then to evaluate the adhesion energy by applying a relevant adhesive model for instance, the JKR model [1]. In our experiments (Fig.1a, b), we have first created a contact between a semi-sphere of elastomer (PDMS) and a glass plate under constant normal force. A shear motion is then performed performed (with different amplitudes) generating a tangential forces smaller than the necessary to trigger the full sliding. Finally, the normal load is reduced until the full separation of the two solids. During the process, high precision measurements of the 6 forces/torques and detailed images of the contact area are obtained.

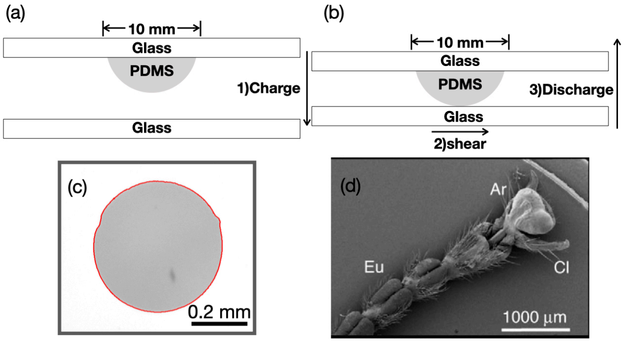

Figure 1: (a), (b) Sketch of the first steps of the experiments: normal loading, slight shear and normal unloading , (c) PDMS-glass interface contact zone, (d) Smooth pad insect leg, from [3]

3.Discussion

As a first result, we study the pull-off force necessary to get out of contact and compared two situations: with and without initial shear. The sphere radius is about 10 mm, and the normal load is such that the radius is a few 100µm (Fig. 1c). The results show a decrease in pull-off force of the order of 50% for an initial shear as small as 10 microns. Such a drastic decrease in pull-off forces could be used as a method to separate surfaces in a possibly more efficient way that simple normal pulling.

In order to access the shear-induced evolution of the adhesion energy, we will discuss the outcomes of adhesive models that accounts for tangential forces [2]. We will also present a detailed study of the contact zone, looking for: peeling, local micro sliding and/or macro sliding induced by the vertical unloading. Those insights could be useful when trying to explain how smooth pad insects can walk on smooth surfaces, without using too much energy at each step [3].

4.References

1. Johnson, K. L. et al. “Surface energy and the contact of elastic solids,” Proceedings of the royal society of London. A. mathematical and physical sciences, 324, 1558, 1971, 301-313.
2. Papangelo, A. et al. “Shear induced contact area anisotropy explained by a fracture mechanics model,” Physical Review E, 99, 5 , 2019, 053005
3. Bullock, J. M. et al. “Comparison of smooth and hairy attachment pads in insects: friction, adhesion and mechanism for direction-dependence,” Journal of experimental Biology, 211, 20, 2008, 3333-3343