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Effect of coating thickness on the friction properties of rubber-sphere on rubber-coated-plane contacts

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Résumé :

Nous présentons une étude expérimentale du frottement d'un contact entre une sphère caoutchouteuse et une lame de verre revêtue d'un film de caoutchouc d'épaisseur variable. Nous montrons que le dépôt joue un rôle clé dans les propriétés de rupture de l'interface de contact : des variations d'un facteur trois du coefficient de frottement statique sont observées lorsque l'épaisseur est modifiée. Certaines interprétations sont discutées pour expliquer le phénomène impliquant notamment le rôle de la viscoélasticité du caoutchouc.

Mots clefs : frottement statique, caoutchouc, contact sphère/plan, revêtement élastomère, épaisseur de film

Abstract :

We present an experimental investigation of the changes in friction at the contact between a rubber sphere and a glass plate coated with a rubber film of variable thickness. We show that the coating plays a key role in the rupture properties of the contact interface: variations of the static friction coefficient by a factor of three are observed when the thickness is varied. Some interpretations are discussed involving especially the viscoelasticity of the rubber.

Keywords: static friction, rubber, sphere on plane contact, elastomeric coating, film thickness

1 Introduction

There are many common situations where contact interfaces involving elastomers are used for adhesion and/or friction functions: for example tire/road contacts in the automotive industry or plunger/syringe contacts in medicine. For decades, a growing interest has developed in controlling friction through surface modification (see e.g. [1]), with the main effort being on topographical features (see e.g. [2]). From a general standpoint, we are interested in understanding how a chemical texturation affects and controls the sliding properties between solids

2 Experimental setup

To bring response elements to the problematic and lift technological obstacles, we realize friction experiments at imposed loading velocity, involving a rubber sphere in contact with an elastomeric film of variable thickness (Fig. 1). The coating and the sphere are made in a well-known silicone elastomer Dow Corning Sylgard 184. The coating thickness varies on six decades, from nanometer to millimeter. The idea here is both to characterize the behavior of a single asperity and to establish the effect of the thickness of a coating before performing chemical modulations in space.

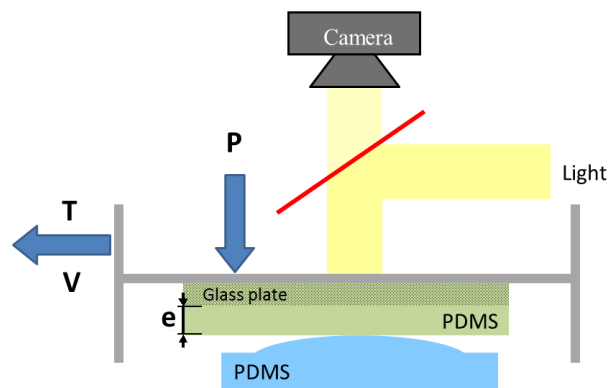


Fig.1 Sketch of the experiment: a spherical elastomer (polydimethylsiloxane, PDMS) lens is in contact with a glass plate coated with a PDMS film of variable thickness e . The tangential load T inducing the tangential movement is recorded for a series of film thicknesses under constant normal load P applied to the sphere. The loading velocity V is imposed.

3 Results

First, we show that the coating has a pronounced effect in the rupture properties of the contact interface. The results are reported in Fig. 2. In the bulk coating case, variations of the static friction coefficient $\mu_s = T_{max}/P$ by a factor of three are observed when the thickness is varied. More precisely, for a micrometric overlay, the coefficient is found close to 0.4 when for millimetric one, we observe a plateau in μ_s around 1.3. The transition between the increasing regime at small scales and plateau corresponds to a thickness of $e \sim 1\text{mm}$. A nanometric coating is obtained by PDMS molecules grafting. For this texturation, we observe a static friction coefficient of 0.2, value lower than the smallest value obtained in the bulk coating case. All these results show a clear mechanical effect on the rupture properties and suggest a volumic contribution. The variation of the static coefficient can be interpreted as the sum of two contributions: a surface dissipation due to adhesive friction at the interface and a volume dissipation resulting from the rubber viscoelasticity.

We then show how to exploit this dissipation through the example of a spatially heterogeneous coated surface.

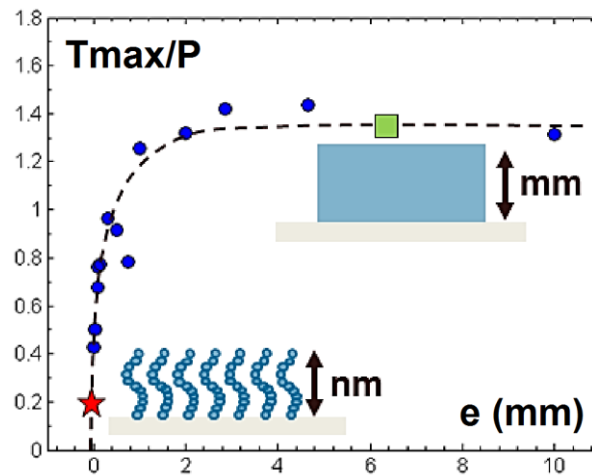


Fig.2 Experimental static friction coefficient $\mu_s = T_{max}/P$ of a contact between a sphere of PDMS and a glass plate coated with a film of the same elastomer of variable thickness e .

4 Conclusion

We have realized an experimental investigation of the coating effect thickness on the friction properties between a rubber-sphere and a rubber-coated-plane. We show that the coating has a pronounced mechanical effect. The variation of the static friction coefficient can be induced by the rubber viscoelasticity properties and to validate this assumption, we plan to realize experiments at different loading velocities.

Références

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