Loading history dependence of tackiness in adhesive soft viscoelastic contacts

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Abstract: Adhesion in soft materials is gathering more and more attention due to the growing interest in soft robotics and bio-inspired engineering. Polymers, elastomers are generally preferred when applications require “flexibility” and safe operation in collaboration with human beings. Furthermore soft end-effectors are often preferred for handling and manipulation of fragile objects, food, and in case of interactions with human beings. In this respect it is important to develop models capable of predicting the adhesive behavior of soft interfaces. There has been a strong interest in the last decade in interfacial patterning for improving macroscopic adhesion, by leveraging on the concept of contact splitting, nevertheless most of the numerical/theoretical contributions have focused on elastic materials. Here, we will consider the effect of viscoelasticity, in particular the dependence of the maximum force reached at detachment on the loading protocol (preload, loading/unloading rate). Recent literature has focused on the adhesion of a spherical probe that indents a viscoelastic substrate showing that the pull-off force is strongly dependent on the history of the contact. Nevertheless we show that if one turns to flat geometry, alike the geometry usually adopted for patterned interfaces, that indents a viscoelastic substrate, the pull-off force remains almost unchanged whatever the contact history, while showing a strong dependence on the rate of unloading. The numerical results are compared against a cohesive zone model, extended from elasticity to viscoelasticity, which shows a good agreement with the numerical results. Furthermore the influence of the substrate thickness b is shown to play a crucial role. By comparing the substrate thickness with a characteristic fracture length we show that there exits 3 regimes for the pull-off stress σ_{po}: (i) a cohesive region where the theoretical strength of the material can be reached (in principle), (ii) a fracture mechanics scaling where $\sigma_{po} \propto b^{-1/2}$ (iii) the limiting half-plane solution. The problem of being predictive remains, as current modelling focuses on the relation between interfacial toughness and crack speed. The latter is usually not easy to determine both numerically and experimentally, being usually the loading/unloading rate the quantity imposed during the numerical/experimental tests. The talk closes with open questions and possibility to improve/regulate actively interfacial macroscopic adhesion through micro-vibrations.

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