M2 internship and PhD thesis (2023)

Understanding the debonding criterion of a microscopic fibril of soft polymer

Laboratoire de Physique des Solides, Laboratoire FAST & Laboratoire de Mécanique Paris-Saclay

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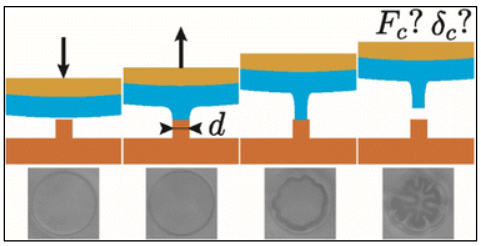
Omnipresent in the industry, both in advanced applications and in connection with our daily lives, adhesive tapes made of soft polymers remain only partially described. The quantitative prediction of their adhesion strength is a difficult fundamental problem, at the frontier between fracture mechanics, material rheology and polymer physics. Besides, the possibility of this prediction is a strong industrial challenge that would allow manufacturers to reduce their development and production costs.

During the detachment of a soft polymer adhesive, the unconfinement of the thin layer of adhesive material most often leads to a process of cavitation or fingering of the detachment front. The scenario then continues with the creation of microscopic fibrils of adhesive material followed by their stretching until they debond. A key theoretical element currently missing to build a predictive model is the understanding of the individual fibril detachment criterion.

The M2 internship and the PhD thesis will be dedicated to the experimental and theoretical understanding of the debonding process of fibrils of soft adhesive material. Different adhesives will be brought into contact with a micrometric pillar before being separated at controlled velocity. During this separation, a single fibril of adhesive material with a diameter controlled by that of the pillar will be created and then stretched until it detaches (see figure). These experiments, which follow a preliminary study published in 2022 [1], will involve the synthesis of adhesives with controlled properties, the characterization of their rheology, the synthesis of textured substrates by electronic and laser lithography and, during the experiments, the measurement of low contact forces coupled with microscopic imaging.



In parallel, modeling and simulation of the pillar-adhesive system will be carried out using the finite element method. Specific techniques [2] will be implemented in order to deal with the viscous response of the adhesive, the progressive debonding at the adhesive-substrate interface (described via cohesive zone models), as well as the unstable response observed in some of the configurations.

The objective of the project is to identify the physical laws that control the debonding of a microscopic fibril of soft adhesive and their dependence on the rheology of the materials, their surface properties and the geometry.

The internship and the thesis will be carried out at Laboratoire de Physique des Solides and Laboratoire FAST, both hosted by Université Paris-Saclay, where the experimental activities will be developed. The theoretical description of the experiments will be carried out in collaboration with LMPS at ENS Paris-Saclay.

[1] A. Duigou-Majumdar, P.-P. Cortet, C. Poulard, Soft Matter **18**, 5857 (2022). https://doi.org/10.1039/D2SM00532H
[2] F. Daghia, V. Fouquet, L. Mabileau, International Journal of Solids and Structures **254-255**, 111910 (2022). https://hal.archives-ouvertes.fr/hal-03741962