Cutting soft materials

Cutting is a ubiquitous process with wide ranging implications, culturally and technologically. Experimenting on the kitchen table, we quickly learn that the easiest way to cut soft solids with a knife is by a slicing action, i.e., dragging the sharp blade over the soft surface without pushing too strongly into it; indeed, pushing the edge of a knife too strongly into a soft solid only squashes it. Moreover, applying a compression in a plane orthogonal to the direction of cutting can be of great help for guiding the cut. However, more generally the forces applied for both cutting and holding the object are responsible for uncomfortable large strains, which induce strong perturbations in the final shape of the parts. Beyond these everyday examples, the cutting of soft materials is of great interest in industrial food processing, in tissue analysis in the context of histology, etc. [1].
The initial developments of cutting science and technology were mostly devoted to metal machining and focused on plastic deformations induced by the motion of the blades though the material. The importance of fracture toughness in cutting was only acknowledged in the 60's after the development of linear elastic fracture mechanics, leading to important advances in the understanding of cutting mechanics of more brittle materials [2]. However, a unifying physical view of cutting that may be suitable for a larger class of materials is still lacking, especially for soft materials. The standard tools of linear elastic fracture mechanics are not suited to treat a problem where the driving arises directly at the crack lips instead of remotely. The local crack fields are strongly coupled with the shape and motion of the blade, involving subtle adhesion and friction problems. In this context the fracture energy and direction of propagation are not independent of shape of the blade and new tools have to be developed to describe them. Although the case of soft materials is of particular importance for many industrial applications, very few tools are available to deal with the very strong nonlinear deformations at different scales, which make it difficult to cut parts of the desired shape and with good surface finish.

This project aims at performing cutting experiments on model soft materials in controlled situations, in order to bridge this gap, while profiting of the significant advances that have recently been made on fracture and adhesion of soft dissipative materials [3]. On the one hand, we aim at clarifying the relevant notions of cutting energy and directionality of the cut as a function the shape and motion of the blade. On the other hand, we intend to develop tools for predicting the final shape of the cut parts in order to allow forward design.
The candidate is expected to have background knowledge in either materials science of solid mechanics.

[1] E. Reyssat, T. Tallinen,1, M. Le Merrer, and L. Mahadevan. Slicing Softly with Shear. PRL 109, 244301 (2012).
[2] T. Atkins. The Science and Engineering of Cutting (2009).
[3] C. Creton and M. Ciccotti. Fracture and adhesion of soft materials : a review, Reports on Progress in Physics, 79, Art N. 046601 (2016).

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