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COMPUTATIONAL OPTIMIZATION OF FLEXIBLE ADHESIVES

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Thin and flexible adhesives are important to various natural and technical applications. These include both the adhesion mechanism of several lizards or insects and the fabrication of bio-inspired adhesives. In recent years, the design of materials with strongly adhesive surfaces has gained interest. This motivates us designing flexible adhesive structures according to desired adhesion and detachment properties.

We present computational optimization of flexible adhesives for various objectives and constraints. For this purpose, we study the peeling behavior of a thin and elongated strip, adhering to the substrate. The structure is modeled by considering a nonlinear finite element formulation that captures large displacements during peeling. This model accounts for the dynamic peeling behavior of the strip.

As design variables, we consider 1) the shape and 2) material and adhesion parameters. The strip is designed according to various criteria; these include

1) the maximization of the peak reaction force,
2) the maximization of the total contact area,
3) the minimization of the strip volume, and
4) the minimization of the strain during peeling.

In a first step, those objectives are discussed individually. Further, essential design constraints on the strip geometry are determined. The different criteria are then combined into a multi-objective problem. To increase efficiency on one hand and to account for the problem's non-linearity on the other hand, we solve the optimization problem with a combined gradient-stochastic approach.

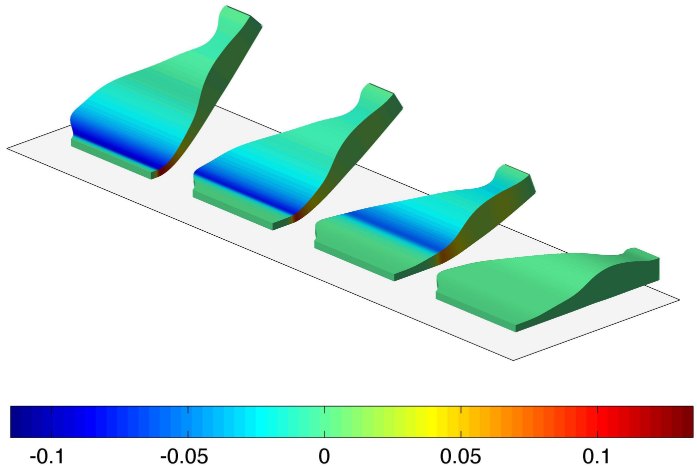

Figure 1: Peeling process of an adhesive microstructure that is shaped like a gecko spatula; shown is only one half of the structure (Figure adopted from [2]).

As a computational example, we present designed adhesives for multiple length scales. The first example considers peeling tapes at the macro-scale for varying peeling directions. The second example discusses adhesive fibrils in the range of the gecko adhesion mechanism. To increase efficiency, a geometrically exact beam finite element formulation is applied. We show that the proposed framework is general; it readily carries over continuum models as well as various contact models considering arbitrary length scales.

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