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Characterisation of the Fracture and Healing of a Feather

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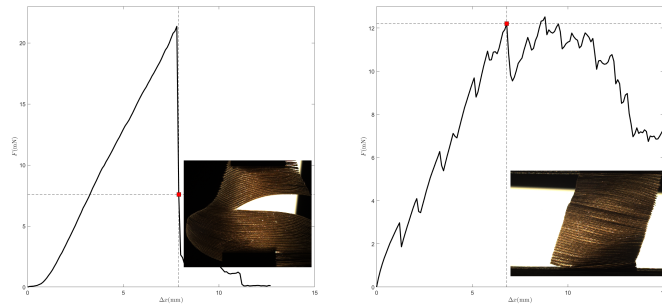


Fig. 1: Mechanical tests on real feathers. Left, experimental uni-axial traction loading curve. Right, experimental shear loading curve.

Feathers are composed of a central shaft, the *rachis*, from which hundreds of fibers called *barbs* branch out. The distinctive surface of a feather is composed of these barbs attached to each other by a myriad of micro-metric spring-like fibres known as *barbules*. This multi-scale architecture grants feathers peculiar properties essential to the flight of birds. Under loading, the feather surface follows an elastic response until barbules start to disengage, yielding tearing of the surface. In contrast to fracture in solids, a crack in a feather propagates along a predetermined path aligned with the barbs, and can be repaired by carefully pushing the barbs back together [2]. Modelling such an interesting reversible mechanical behaviour is of great importance not only to gain a better understanding of feathers, but also to design new meta-materials with healing properties.

In our work, we first conduct tensile and shear tests on rectangular patches cut from real feathers in order to characterise the behaviour of a feather, as shown in Figure 1. We do not take into account the rachis as we consider that the local mechanical response is governed by the interplay between barbs and barbules. From this geometrical and mechanical characterisation, we then develop a simple numerical model at the scale of the feather surface, by taking inspiration from thin sheet simulators possessing fracture capabilities, as in [1]. To model the healing process, we add a repair mechanism to the simulator. We furthermore account for a real barb distribution projected onto the surface to enforce realistic anisotropy in the elastic, fracturing, and healing behaviours of the surface. We finally validate our numerical model against various experiments.

References

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- [2] F. Zhang, L. Jiang, and S. Wang. “Repairable cascaded slide-lock system endows bird feathers with tear-resistance and superdurability”. In: *Proceedings of the National Academy of Sciences* 115 (2018), pp. 10046–10051.