A regularised damage-failure constitutive model of the *stratum corneum*

Georges Limbert[1,2,3]

[1] national Centre for Advanced Tribology [2]Bioengineering Science Research Group
Faculty of Engineering and the Environment, University of Southampton
University Road, Southampton SO17 1BJ, UK, g.limbert@soton.ac.uk,
www.insilicomechanobiology.com

[3] Biomechanics and Mechanobiology Laboratory, Division of Biomedical Engineering
Department of Human Biology, Faculty of Health Sciences, University of Cape Town
Observatory 7935, South Africa, www.biomechanics.uct.ac.za

Key Words: *damage, failure, hyperelasticity, energy limiter, mass sink, soft tissue, stratum corneum, skin*

The *stratum corneum* (SC) which is the 10-30 μm thick outermost layer of the skin is pivotal in conditioning the mechanics of the skin [1, 2]. It can stiffen by up to three orders of magnitude, in a matter of hours, when relative humidity levels drop from 100 to 0% [3]. In these conditions, the SC can easily fracture under moderate strains and this phenomenon has important mechanobiological consequences by triggering detrimental tissue responses such as inflammation, scarring and desquamation. These effects can aggravate skin disorders such as atopic dermatitis, *ichtyosis vulgaris* and chronic xerosis. It is therefore essential to gain a mechanistic insight into the facture behaviour of SC so that preventive and treatment solutions could be devised.

The objective of this research was to devise a thermodynamically-sound constitutive framework to account for the fracture and failure behaviour of the SC whilst also bypassing a built-in limiting assumption of continuum mechanics, namely *locality*. In a finite element context, damage localisation zones are associated with pathological mesh dependency.

Departing from traditional non-local continuum damage mechanics and phase field approaches, here, following the idea of Volokh [4], it is proposed to treat brittle fracture of a continuum as a material sink. A mass balance equation featuring a mass sink is coupled to elastic finite deformation equations through a characteristic length and a strain energy limiter. The model was calibrated using experimental data [3] and implemented in a multi-field finite element formulation featuring displacement and density as degrees of freedom.

Besides its conceptual simplicity and regularised nature, this constitutive model is free from any internal variables and only requires parameters that can be characterised experimentally.

REFERENCES

[1] M.F. Leyva-Mendivil, A. Page, N.W. Bressloff and G. Limbert, A mechanistic insight into the mechanical role of the stratum corneum during stretching and compression of the skin. *J. Mech. Behav. Biomed. Mater.*, **49**(0), pp.197-219, 2015

[2] G. Limbert, Mathematical and computational modelling of skin biophysics-A review. *P. Roy. Soc. A-Math. Phys.*, **473**(2203), pp.1-39, 2017

[3] K. S. Wu, W. W. van Osdol and R. H. Dauskardt, Mechanical properties of human stratum corneum: effects of temperature, hydration, and chemical treatment. *Biomaterials*, **27**(5), pp. 785-795, 2006

[4] K. Y. Volokh, Fracture as a material sink. *Mater. Theory*, 1(1):3, 2017