Morphoelastic remodeling of collagenous fibers under cyclic loading

Heiko Topol[(a)], *Hasan Demirkoparan*[(a)], *Thomas J . Pence*[(b)]

❑[(a)] Carnegie Mellon University Qatar, P.O. Box 24866, Doha, Qatar (htopol@qatar.cmu.edu, hasand@qatar.cmu.edu)

❑[(b)] Department of Mechanical Engineering, Michigan State University, East Lansing, MI 48824-1226, USA (pence@egr.msu.edu)

Soft tissues undergo remodeling processes, which are related to numerous biological, chemical and physical processes. Different experiments such as [1] find that enzymatic collagen fiber dissolution is slowed down when the fibers are stretched. This effect has been taken into account in a continuum mechanics framework by Demirkoparan et al. [2]. In this continuum mechanics framework the mechanical properties of the fibers have been modeled in terms of the strain energy density of basic fiber entities, so-called protofibers, and a fiber survival kernel, which describes the development of the fiber density with the deformation history of the material. This kernel is modeled in terms of a constant fiber creation rate and a mechano-sensitive fiber dissolution rate, which decreases with the amount of fiber stretch. The ground substance matrix of the material is taken to be an incompressible neo-Hookean solid, which despite its simplicity may provide a sufficient accuracy in describing the ground substance properties.

The natural or undeformed configuration of the fibers may differ from the natural configuration of the ground substance matrix. In different loading scenarios such as swelling [3] and cylindrical inflation [4] it has been shown that the choice of the natural fiber configuration has a crucial impact on the development of the fiber properties.

In our work we study the development of relation between loading and deformation of the material for different fiber natural configurations, which may results into stiffening or softening of the material with cyclic loading. The fibers natural configuration may coincide with the natural configuration of the surrounding ground substance matrix, or the fiber may be synthesized in a state of pre-stretch.

Acknowledgement: This work was made possible by NPRP Grant No.8-2424-1-477 from the Qatar National Research Fund (a member of the Qatar Foundation). The statements made herein are solely the responsibility of the authors.

[1] A. P. Bhole, B.P. Flynn, M. Liles, N. Saeidi, C. Dimarzio, J. Ruberti, Philos. Trans. R Soc. Lond. A 367: 3339-3362 (2009)

[2] H. Demirkoparan, T.J. Pence, A. Wineman, Int. J. Nonlinear Mech. 56:86–93 (2013)

[3] H. Topol, K. Gou, H. Demirkoparan, T.J. Pence, Biomech. Model.Mechan. 17:1543-1567 (2018)

[4] H. Topol, H. Demirkoparan, T.J. Pence, Eur. J. Mech. A – Solid (submitted) (2019)