A Crack Phase-field Model to Analyze Aortic Dissections

Gerhard A. Holzapfel[*,†], **Osman Gültekin**[*,‡], **Sandra Priska Hager**[*,§] **and Hüsnü Dal**[‡]

[*] Graz University of Technology, Institute of Biomechanics, Austria
e-mail: holzapfel@tugraz.at

[†] Norwegian University of Science and Technology (NTNU)
Department of Structural Engineering, Norway

[‡] Middle East Technical University, Department of Mechanical Engineering, Ankara, Turkey
e-mail: {osmang|dal}@metu.edu.tr

[§] Kings College London, Faculty of Life Sciences and Medicine, UK
e-mail: sandra.p.hager@kcl.ac.uk

This study analyzes the lethal clinical condition of aortic dissections from a numerical point of view. On the basis of our previous contributions [1,2], we apply a holistic geometrical approach to fracture, namely the crack phase-field, which inherits the intrinsic features of gradient damage and variational fracture mechanics. The continuum framework captures anisotropy, is thermodynamically consistent and based on finite strains. The balance of linear momentum and the crack evolution equation govern the coupled mechanical and phase-field problem. The solution scheme features the robust one–pass operator–splitting algorithm upon temporal and spatial discretizations. Based on experimental data of diseased human thoracic aortic samples, the elastic material parameters are identified followed by a sensitivity analysis of the anisotropic phase-field model. Finally, we simulate an incipient propagation of an aortic dissection within a multi–layered segment of a thoracic aorta that involves a prescribed initial tear [3]. The finite element results demonstrate a severe damage zone around the initial tear, exhibit a rather helical crack pattern, which aligns with the fiber orientation.

REFERENCES

[1] Gültekin, O., Dal, H. and Holzapfel, G.A., A phase-field approach to model fracture of arterial walls: theory and finite element analysis, *Comput. Meth. Appl. Mech. Eng.* (2016) **312**:542–566.

[2] Gültekin, O., Dal, H. and Holzapfel, G.A., Numerical aspects of anisotropic failure in soft biological tissues favor energy-based criteria: A rate-dependent mixed crack phase-field model, *Comput. Meth. Appl. Mech. Eng.* (2018) **331**:23–52.

[3] Gültekin, O., Priska Hager, S., Dal, H. and Holzapfel, G.A., Computational modeling of progressive damage and rupture in fibrous biological tissues: Application to aortic dissection, submitted.