A Phase-Field Approach to Model Fracture of Arterial Walls

Osman Gültekin[1*], Hüsnü Dal[2], Gerhard A. Holzapfel[1]

[1]Institute of Biomechanics
Graz University of Technology
Stremayrgasse 16/2, 8010, Graz, Austria
{gueltekin, holzapfel}@tugraz.at

[2]Department of Mechanical Enginering
Middle East Technical University
Dumlupinar Bulvari, No.1, Cankaya , 06800, Ankara, Turkey
dal@metu.edu.tr

ABSTRACT

Over the last decades the supra-physiological and pathological aspects of arterial tissues have become a prominent research topic in computational biomechanics in regard to constitutive modeling considering damage and failure.

In the present study a recently developed incremental variational phase-field model [1] for quasi-brittle fracture, featuring thermodynamic consistency, is extended to the finite deformation anisotropic material behavior of soft biological tissues by exploiting a continuous formulation of the variational principle which results in coupled balance equations, i.e. the balance of linear momentum describing the deformation field and the local evolution of the phase-field [2]. On the numerical side, a canonical Galerkin-type finite element procedure together with a standard discretization renders the algebraic counterparts of the weighted residual expressions and the symmetric tangent matrices in a monolithic scheme. We consider the crack growth driven by an energetic criterion associated with the constitutive model as developed in [3]. In what follows is a partition of the monolithic solution scheme according to the staggered solution scheme, which successfully updates the history field described by the failure criterion, the crack phase-field and the deformation field.

Finally, we demonstrate the theoretical and numerical performance of the novel crack phase-field model that captures the fracture phenomenon in anisotropic materials through fittings against a set of recent experimental data obtained from both quasi-static uniaxial and shear experiments carried out on arterial wall segments. The results show an excellent match with the experimental results.

References

[1] C. Miehe, F. Welschinger, M. Hofacker, Thermodynamically consistent phase-field models of fracture: Variational principles and multi-field FE implementations. Int. J. Numer. Meth. Eng. 83:1273--1311, 2010.
[2] O. Gültekin, H. Dal, G.A. Holzapfel. A phase-field approach to model fracture of arterial walls: theory and finite element analysis. Submitted.
[3] G.A. Holzapfel, T.C. Gasser, R.W. Ogden. A new constitutive framework for arterial wall mechanics and a comparative study of material models. J. Elasticity. 61:1--48, 2000.