8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineeering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

A Comparative Study of Different Material Models for the Simulation of Arterial Walls

*** D. Brands[1], A. Klawonn[2], O. Rheinbach[2], and J. Schröder[1]**

[1] Institut für Mechanik, Abt. Bauwissenschaften,
Fakultät für Ingenieurwissenschaften
Universität Duisburg-Essen,
45117 Essen, Universitätsstr. 15, Germany

[2] Lehrstuhl für Numerische Mathematik
Fachbereich Mathematik
Universität Duisburg-Essen,
45117 Essen, Universitätsstr. 3, Germany

Key Words: *anisotropic, biological soft tissues, domain decomposition, FETI, parallel computing, polyconvex.*

ABSTRACT

The computational simulation of medical treatments in the field of arterial diseases, e.g., ballon-angioplasty, requires suitable material models to describe the mechanical behavior of the soft biological tissues. In this contribution we focus on material models for arterial walls. We consider several polyconvex material functions representing such materials, see [1, 2, 3], and study the influence on the mechanical response and the numerical performance.

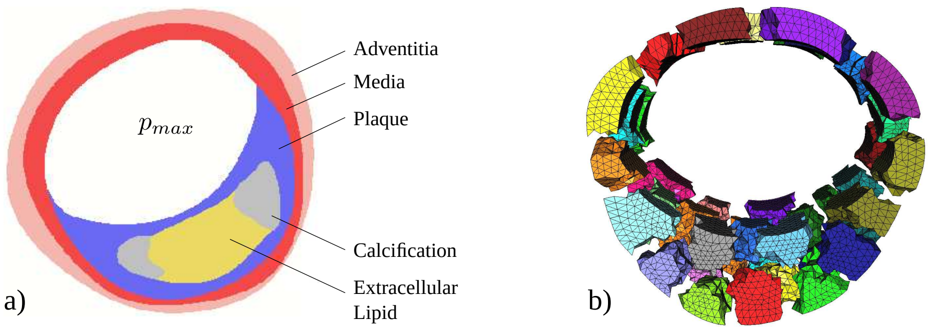

Figure 1: a) Cross-section and b) decomposition of the arterial model; see [3].

For the comparability of the results we adjust the parameters of the material functions to experimental data. The numerical simulation is accomplished using a three dimensional model of a diseased artery. The geometrical model is built from the cross-section considered in Figure 1a by an extrusion in the direction orthogonal to the plane. The model consists of the media and the adventitia, which are assumed to be undiseased, and three plaque components: the plaque itself which can be interpreted as diseased intima, two calcification areas and an extracellular lipid pool. In the healthy part of the artery, cf. upper part in Figure 1a, we do not account for the intima, as we assume that the influence of a healthy intima on the mechanical properties is negligible.

For the discretization of the model we use 10-noded tetrahedral elements and assume a statically determined system. In all simulations we apply a pressure of up to 24 kPa ($\approx$ 180 mmHg) to the interior of the arterial segement, which is in the upper range of physiological blood pressure.
We perform a parallel solution of the resulting linearized system using a domain decomposition method, which belongs to the family of Finite Element Tearing and Interconnecting - Dual Primal (FETI-DP) methods; see [4, 5, 6] and references therein. During the solution process, the arterial segment is decomposed as shown in Figure 1b.
As a characteristic for the material response we compute the von Mises equivalent stress σ_v and the stresses $\sigma_{A^{(i)}}$ along the directions of the fibers in the arterial layers. To take into account the influence of the different models on the nonlinear iterations as well as on the FETI-DP iterative linear solution process, we monitor the number of global Newton steps, the number of (inner) FETI-DP iterations within each Newton step, and the residual norm of the Newton steps; see Figure 2.

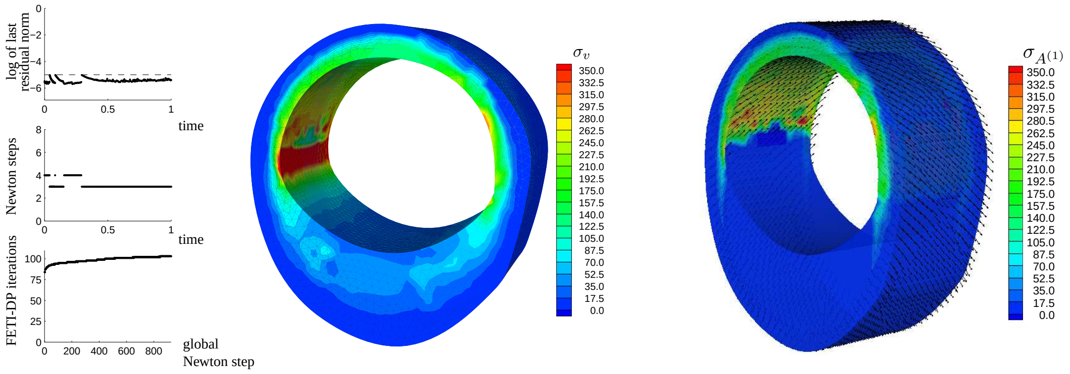

Figure 2: Results from numerical simulation; see [3].

Acknowledgements: The work of the authors was financially supported by the Deutsche Forschungsgemeinschaft (DFG) under research grants KL 2094/1-1 and SCHR 570/7-1. We also acknowledge the scientific support by Prof. Dr. G. A. Holzapfel (TU Graz), Dr. D. Balzani (Universität Duisburg-Essen), and Prof. Dr. med. R. Erbel, Dr. med. D. Böse (both Universitätsklinikum Essen) for scientific support.

REFERENCES

[1] D. Balzani. *Polyconvex Anisotropic Energies and Modeling of Damage Applied to Arterial Walls*. Phd thesis, University Duisburg-Essen, Verlag Glückauf Essen, 2006.

[2] D. Balzani, P. Neff, J. Schröder, and G.A. Holzapfel. A polyconvex framework for soft biological tissues. Adjustment to experimental data. *Int. J. Solids Struct.*, 43(20):6052–6070, 2006.

[3] Dominik Brands, Axel Klawonn, Oliver Rheinbach, and Jörg Schröder. Modeling and convergence in arterial wall simulations using a parallel FETI solution strategy. *Computer Methods in Biomechanics and Biomedical Engineering*, 2007. submitted.

[4] C. Farhat, M. Lesoinne, P. LeTallec, K.H. Pierson, and D. Rixen. FETI-DP: A dual-primal unified FETI method - part I: A faster alternative to the two-level FETI method. *Internat. J. Numer. Methods Engrg.*, 50:1523–1544, 2001.

[5] A. Klawonn and O. Rheinbach. A parallel implementation of dual-primal FETI methods for three dimensional linear elasticity using a transformation of basis. *SIAM J. Sci. Comput.*, 28(5):1886–1906, 2006.

[6] A. Klawonn and O.B. Widlund. Dual-primal FETI methods for linear elasticity. *Comm. Pure Appl. Math.*, 59:1523–1572, 2006.