11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

ASPECTS OF ARTERIAL WALL SIMULATIONS: NONLINEAR ANISOTROPIC MATERIAL MODELS AND FLUID STRUCTURE INTERACTION

Daniel Balzani[1], Simone Deparis[2], Simon Fausten[1*], Davide Forti[2], Alexander Heinlein[3], Axel Klawonn[3], Alfio Quarteroni[2], Oliver Rheinbach[4], and Jörg Schröder[1]

[1] Institute of Mechanics, University of Duisburg-Essen, Universitätsstraße 15, 45141 Essen, Germany,
[2] Chair of Modeling and Scientific Computing, MATHICSE - EPFL, Station 8, 1015 Lausanne, Switzerland
[3] Mathematical Institute, University of Cologne, Weyertal 86-90, 50931 Köln, Germany
[4] Institute of Numerical Mathematics and Optimization, TU Bergakademie Freiberg, Akademiestraße 6, 9599 Freiberg, Germany

Key words: *Arterial Walls, Finite Element Method, Nonlinear Solid, Fluid Structure Interaction, Parallel Calculation.*

The computational simulation of atherosclerotic arteries is of high importance with respect to an optimization of medical treatment by reducing the number of animal tests. The physiological loading situation of arteries with a moderate atherosclerotic plaque is particularly interesting because here it is often difficult for medical doctors to estimate based on imaging techniques if the plaque is going to rupture and if surgical intervention is required. Therefore, the reliable calculation of transmural stress distributions is required since concentrations of high stresses are often considered as the main origin of plaque rupture. These stresses depend strongly on the material behavior and structure of the arterial wall, the behavior of the blood, as well as their interaction. In this contribution first results of the DACH project "Domain-Decomposition-Based Fluid Structure Interaction Algorithms for Highly Nonlinear and Anisotropic Elastic Arterial Wall Models in 3D" (funded by the German Science Foundation and the Swiss National Science Foundation) are presented. The goal of this project is to develop new methods combining fluid structure interaction approaches, see e.g. [4], and domain decomposition methods, cf. e.g. [6], with nonlinear anisotropic material models for the arterial wall, see e.g. [1], in order to more reliably predict the transmural wall stresses. FETI domain decomposition methods have already shown its applicability for the solution of boundary value problems of the pure solid part of the artery, see e.g. [3]. If the interaction of the fluid and structure is considered, the dynamic response of the arterial wall may become important. Thus, a viscoelastic model based on the approach in [5] is taken into account and its influence on the behavior of the full vessel is analyzed. This model incorporates the viscoelastic response in the main directions of the fibrous components inside the arterial wall. Since patient-specific simulations are one of the goals of this project the construction of realistic geometric models is required. Here, we focus on the so-called virtual histology which provides information regarding a stack of axially distributed two-dimensional cross-section images from which the individual components such as the media and several plaque constituents can be segmented, cf. [2]. First numerical results taking into account the nonlinear anisotropic material model and fluid structure interaction are given in order to show the performance of the developed methods.

REFERENCES

[1] D. Balzani, P. Neff, J. Schröder and G.A. Holzapfel. A polyconvex framework for soft biological tissues. adjustment to experimental data. *International Journal of Solids and Structures*, **43(20)**, 6052–6070, 2006.

[2] D. Balzani, D. Böse, D. Brands, R. Erbel, A. Klawonn, O. Rheinbach, J. Schröder. Parallel Simulation of Patient-specific Atherosclerotic Arteries for the Enhancement of Intravascular Ultrasound Diagnostics. *Engineering Computations*, **29(8)**, 2012.

[3] D. Brands, A. Klawonn, O. Rheinbach, J. Schöder. Modelling and Convergence in Arterial Wall Simulations Using a Parallel FETI Solution Strategy. *Computer Methods in Biomechanics and Biomedical Engineering*, **11(5)**, 1476–8259, 2008.

[4] S. Deparis, M. Discacciati, G. Fourestey and A. Quarteroni. Fluid-structure algorithms based on Steklov-Poincare operators. *Compt. Methods Appl. Mech. Engrg.*, **195**, 5797–5812, 2006.

[5] G.A. Holzapfel and T. Gasser. A viscoelastic model for fiber-reinforced composites at finite strains. Continuum basis, computational aspects and applications. *Compt. Methods Appl. Mech. Engrg.*, **190**, 4379–4403, 2001.

[6] A. Klawonn and O. Rheinbach. Highly scalable parallel domain decomposition mehtods with an application to biomechanics. *ZAMM - Zeitschrift für Angewandte Mathematik und Mechanik - Journal of applied Mathematics and Mechanics*, **90**, 5–32, 2010.