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SIMULATION OF ARTERIAL WALLS UNDER CONSIDERATION OF RESIDUAL STRESSES - A NUMERICAL APPROACH

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Several experimental studies show that eigenstresses are present in arterial walls. When an axial section is cut in longitudinal direction, the artery springs open, see e.g. [3]. The inherent stresses have a significant influence on the overall tissue behavior since they reduce high stress gradients through the thickness of the wall. The "opened" configuration is often assumed to be stress-free. However, this is only an approximation. In various works dealing with the numerical simulation of arterial walls, as for example [1], it is accounted for residual stresses by closing an opened, unstressed artery by an initial bending to form a load-free, but internally stressed configuration. In this contribution we propose a novel approach for the incorporation of residual stresses in patient-specific human arteries, as proposed in [2]. In contrast to the approach described above, we focus directly on the

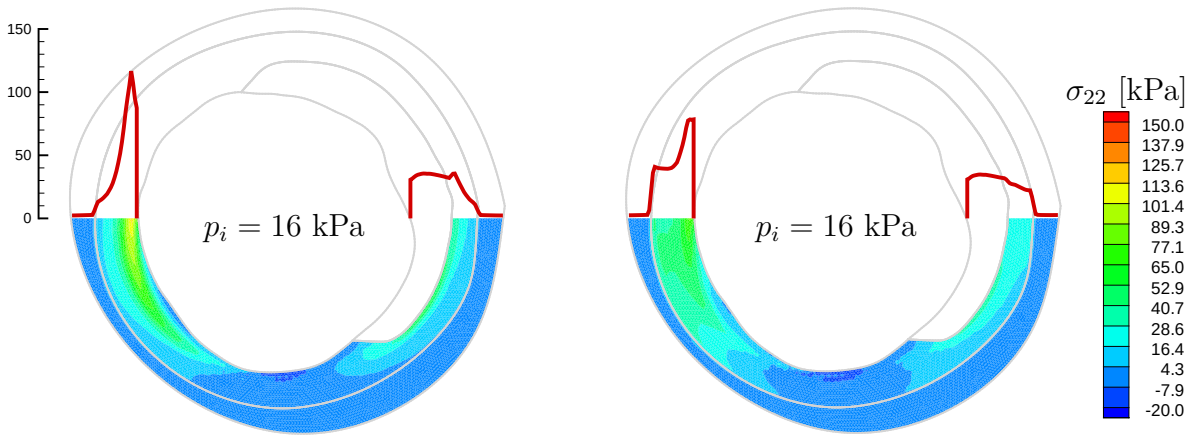

Figure 1: Stress distribution of the σ_{22} stresses without and with residual stresses (left hand side and right hand side, respectively).(taken from [2])

gradients of the fiber stresses in radial direction. As an underlying optimization criterion we assume that these gradients have to be smoothed between the inner and outer margins of the individual layers. In order to do so we define sufficiently small radial sections of the media and adventitia, in which this condition has to be enforced independently. After the superposition of residual stresses to the current stress state a new equilibrium state by solving the balance of linear momentum has to be computed. The smoothing process can be repeated several times until a satisfying distribution is present. In Figure 1 the effects of the assumptions made are demonstrated. Due to residual stresses the stress maximum on the innermost layer decreases and a more uniform distribution is obtained. The impact of the different stiffnesses of the material layers, namely media and adventitia, is kept and still visible. In order to prove the accuracy of the proposed model the opening angle experiment was simulated with the calculated residual stresses and the opening angle was investigated, see e.g. Figure 2.

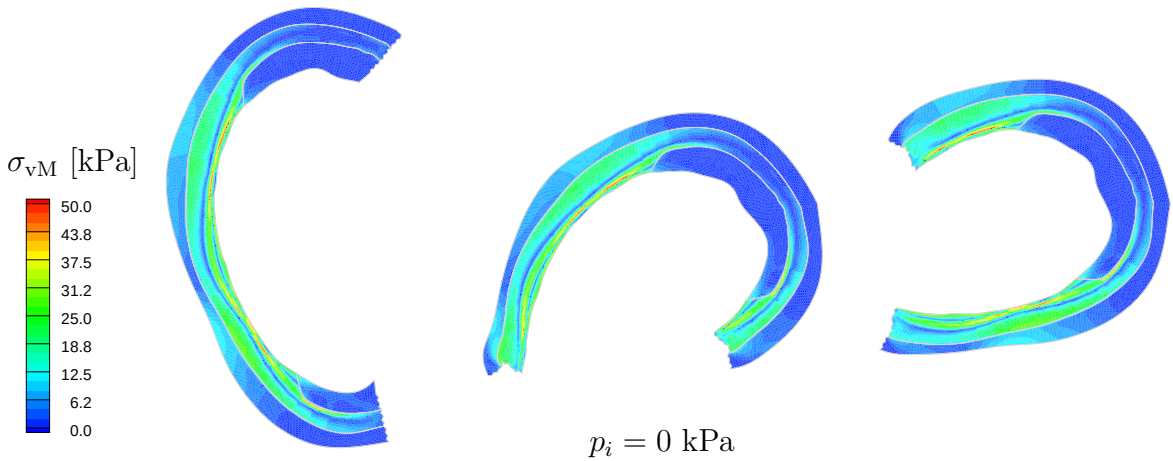

Figure 2: Distribution of the von Mises stress σ_{vM} [kPa] in the opened artery. Different opening angles for different cuts.(taken from [2])

Conclusion: Residual stresses can be approximated by smoothing the circumferential stress gradient. The fiber stresses are suitable scalar stress measures in this context. A method to smooth and project them onto the current prefered direction is derived and discussed for a patient-specific artery.

REFERENCES

[1] V. Alastrué, E. Pẽna, M. Angel, M.A. Martínez, and M. Doblaré. Assessing the use of the "opening angle method" to enforce residual stresses in patient-specific arteries. *Journal of Biomechanical Engineering*, Vol. **35**, 1821-1837, 2007.

[2] J. Schröder and S. Brinkhues. A novel numerical scheme for the computation of residual stresses in arterial walls. accepted, 2014.

[3] R.N. Vaishnav and J. Vossoughi. Estimation of Residual Strains in Aortic Segments. Biomedical Engineering II: Recent Developments, Pergamon Press, New York, 1983.