Multiscale Simulation of Active Biological Multiphase Tissue

Tim Ricken[1]*, Lena Lambers[1], Franziska Egli[1] and Seyed Morteza Seyedpour[1]

[1] Institute of Mechanics, Structural Analysis and Dynamics, Faculty for Aerospace Engineering and Geodesy, University of Stuttgart, Pfaffenwaldring 27, 70569 Stuttgart, tim.ricken@isd.uni-stuttgart.de, https://www.isd.uni-stuttgart.de/

Key Words: *active material, multiphase, multiscale, theory of porous media (TPM).*

Nearly all active biological tissues show a multiphase composition and have a distinct microscopic structure. Examples are the liver, muscle, or cartilage . Their substructures are e.g. pores, fibres with different orientations, or cells which can be influenced by bio-chemical reactions.
The high complexity of those kinds of material makes it reasonable to consider homogenization approaches and multiscale techniques in order to find an effective modeling access for the numerical simulation. This is even more the case since modern experimental methods such as CT-scanning or MRI imaging give us the opportunity to gain a deep insight into the microscale structure, cf. (SEYEDPOUR ET AL. 2021).
Thus, we will present a combined multiphase-multiscale approach for the description of those kinds of materials. The method is based on the well-known Theory of Porous Media (TPM), a continuum-mechanical homogenization approach founded on the mixture theory in combination with the concept of volume fraction, cf. (EHLERS 2002).
Depending on the material, we will combine the TPM with reasonable multiscale techniques such as FE^2 (BARTEL ET AL. 2015) or POD-ODE coupling (LAMBERS ET AL. 2019; RICKEN ET AL. 2015)

REFERENCES

BARTEL, FLORIAN; RICKEN, TIM; SCHRÖDER, JÖRG; BLUHM, JOACHIM (2015): A two-scale homogenisation approach for fluid saturated porous media based on TPM and FE 2 -Method. In: Proc. Appl. Math. Mech. 15 (1), S. 447–448. DOI: 10.1002/pamm.201510214

EHLERS W (2002) Foundations of multiphasic and porous materials. In: Ehlers W, Bluhm J (eds) Porous Media: Theory, experiments and numerical applications. Springer Berlin Heidelberg, Berlin, Heidelberg, pp 3–86

LAMBERS L, RICKEN T, KÖNG M (2019) A multiscale and multiphase model for the description of function-perfusion processes in the human liver. In: Zingoni A (ed) Advances in Engineering Materials, Structures and Systems: Innovations, Mechanics and Applications. CRC Press, pp 304–307

RICKEN T, WERNER D, HOLZHÜTTER HG, KÖNIG M, DAHMEN U, DIRSCH O (2015) Modeling function-perfusion behavior in liver lobules including tissue, blood, glucose, lactate and glycogen by use of a coupled two-scale PDE-ODE approach. Biomech Model Mechanobiol 14:515–536. https://doi.org/10.1007/s10237-014-0619-z

SEYEDPOUR SM, NABATI M, LAMBERS L, NAFISI S, TAUTENHAHN H-M, SACK I, REICHENBACH JR, RICKEN T (2021) Application of Magnetic Resonance Imaging in Liver Biomechanics: A Systematic Review. Frontiers in Physiology 12:733393. https://doi.org/10.3389/fphys.2021.733393