Contribution ID: **352** Type: **Oral Presentation**

Interaction Problems between Fluids and Poro-Elastic Media - Applications in Life Sciences

Thursday, 3 June 2021 10:30 (15 minutes)

The urgent need for a better quantitative understanding of physiological processes in cells, tissues and the whole body is particularly evident in the current pandemic, in which the SARS-CoV2 virus is upsetting vital processes in the infected individuals. The damages of the virus at the cellular level, initially mainly in the lung, are causing inflammation that can get disordered and lead to a life-threatening breakdown of the organ system. An analysis of the processes involved in the infection and the reaction of the immune system shows that their influence on the structure and the biophysical and biochemical properties of the epithelial layers separating compartments in the body, in particular of the endothelium of the blood vessels is decisive. These interfaces determine the course of exchange processes and the vital reactions in the whole organism. Epithelial cell layers are regulators of barrier functions, controlling the transitions between different compartments, the exchange of chemical substances, of ions, of fluids, of cells. They are track switches of signalling and regulators coupling processes in different compartments. On cellular level, membranes and envelopes are playing a similar role, changing their permeability depending on the processes.

Mathematical modelling and simulation of these processes profit a lot from ideas and contributions of Andro Mikelic to multiscale analysis and its applications to porous media, in particular also to poro-elastic media. This report is dedicated to my long-time friend and outstanding partner Andro.

A crucial problem in modelling and simulation is the coupling of diffusion, transport and reactions in a free flow and a flow in a poro-elastic medium. Assume that the elastic medium can be modelled by a Biot-System and that in the epithelial layer can be replaced by the boundary surface of this medium. The question arises: What are the appropriate transmission conditions?

The transmission conditions could be derived in a former joint paper with Andro Mikelic for the pure fluid flow and without an intermediate layer, in case of rigid porous media and under periodicity assumptions, investigating carefully the scale limits. A derivation of the transmission conditions using multiscale techniques is missing in case of poro-elastic media.

We formulated phenomenological transmission condition in two model systems, developed for

- osmotic swelling of a cell, modelled as a poro-elastic Biot medium.
- modeling of the inflammation, the regulation of the endothelial permeability and the formation of plaques.

Both topics lead to free boundary problems. Simulation results will be presented.

This report is based on joint research with Maria Neuss-Radu, Valeria Malieva, Telma Silva, Adelia Sequeira, Yifan Yang.

Time Block Preference

Time Block B (14:00-17:00 CET)

References

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Session Classification: MS24

Track Classification: (MS24 - Invitation Only) Mathematical and computational challenges related to porous media - Special session in memory of Andro Mikelic