Comparison of Heat and Mass Transport at the Micro-Scale

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Introduction: Phenomena of heat and mass transfer are often compared, in various porous media applications. Questions of practical interest are, for example, if tracers can be used for the prediction of heat flow, or vice versa if heat can be utilized as, possibly retarded, tracer for predicting the migration of contaminants, nutrients or other substances. Using numerical modelling in artificial porous media we compute heat and mass transport for pore length scales in the range of micrometers. The simulations show different behaviour of heat and mass, which is due to different values of the relevant parameters (high Lewis number!) and the different physics of transport in the solid phase.

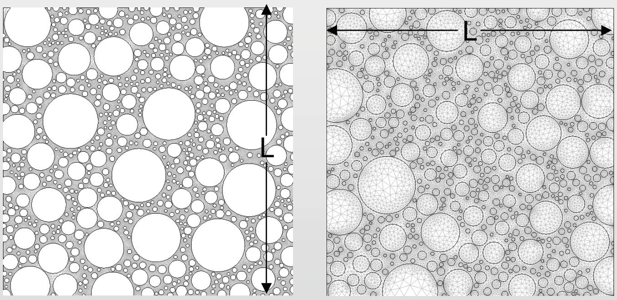

Figure 1. Artificial porous media and FE meshes
left: flow & mass transport; right: heat transport

Model Approach:

- Solution of ***Navier-Stokes*** equations in pore space (stationary)
  - No slip boundary condition at pore surfaces
  - Pressure gradient prescribed
- ***Advection-diffusion*** mode for mass transport in pore space (transient)
  - Molecular diffusivity
  - Concentration specified at inflow
- ***Convection-conduction*** mode for heat transport in pore space and in porous medium (two sub-domains, transient)
  - Temperature specified at inflow

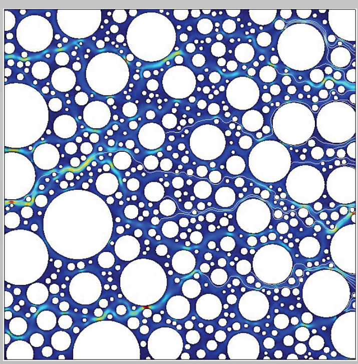

Figure 2. Flow field: absolute value of velocity in pore space

Results: The length scale of the porous system was changed between 1 mm and 1 dm. Heat and mass transfer, using typical parameter values, show very different behavior, in particular concerning arrival times.

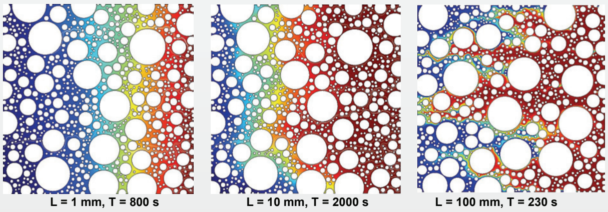

Figure 3. Mass transport at 3 length scales

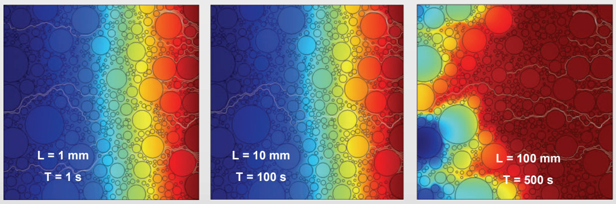

Figure 4. Heat transport at 3 length scales

The different phenomenology of heat and mass transport at the considered length range can be explained with help of analytical solutions for arrival times.

$$T_{diff} = \frac{L^2}{4D\left(erfc^{-1}\left(c/c_0\right)\right)^2}$$

$$T_{adv} = \frac{L}{v}$$

for constant p-gradient: $v \sim L^2$

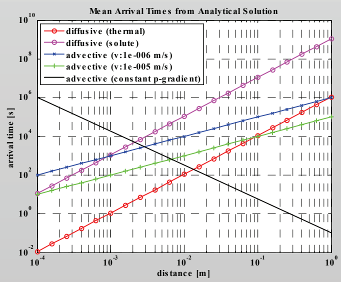

Figure 5. Comparison of arrival times

Conclusions: As a result of the modelling work we find a strong scale dependence.

- At the microscale (<1 mm) heat and mass transport are both diffusion dominated and the differences are determined by the highly unequal diffusivities
- At the large scale (> 1m) heat and mass transfer are advection dominated; heat is retarded
- At the intermediate scale (>1 mm, < 1m) heat transfer is diffusion dominated, while mass transfer is advection dominated; thus incomparable

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