An introduction to membraneFoam

Presentation of the project work for the course
'CFD with OpenSource software',
taught at Chalmers, winter term 2016

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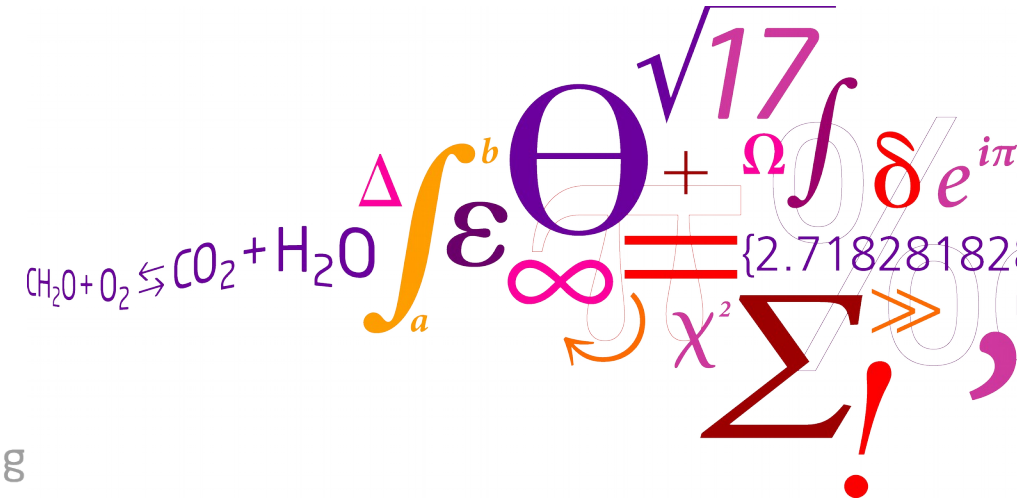


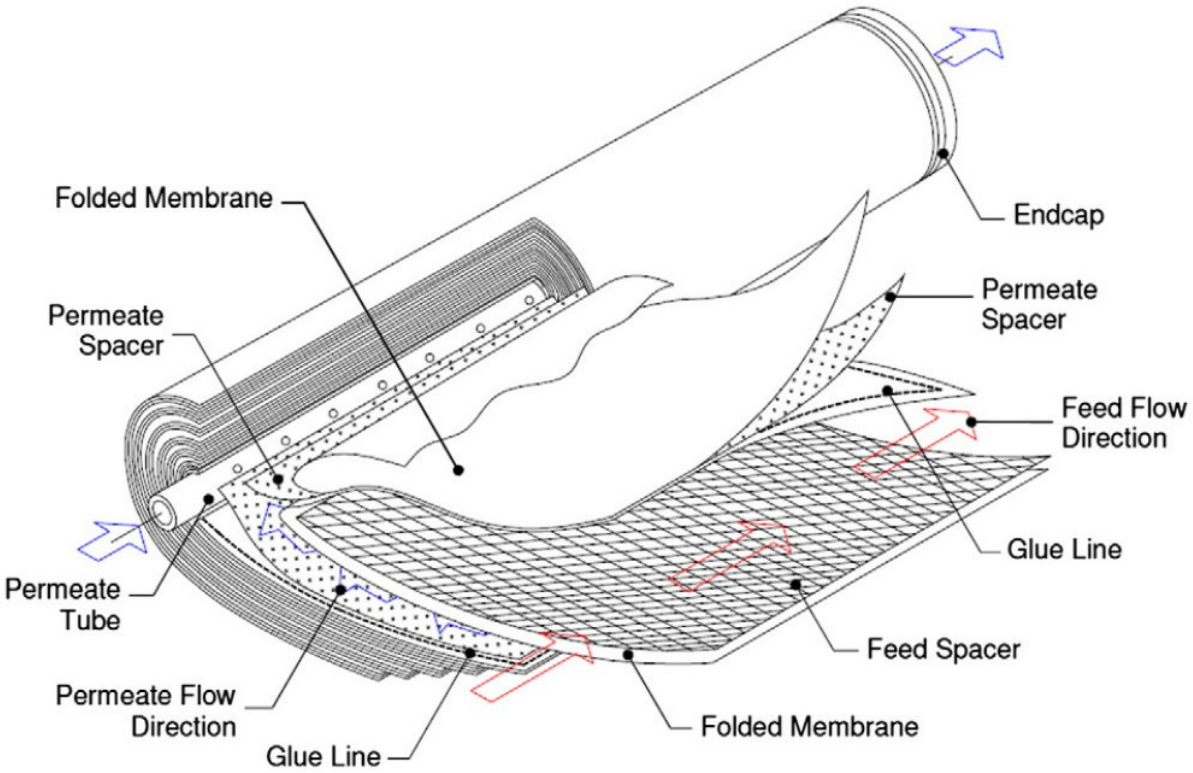
DTU Environment
Department of Environmental Engineering

Presentation outline

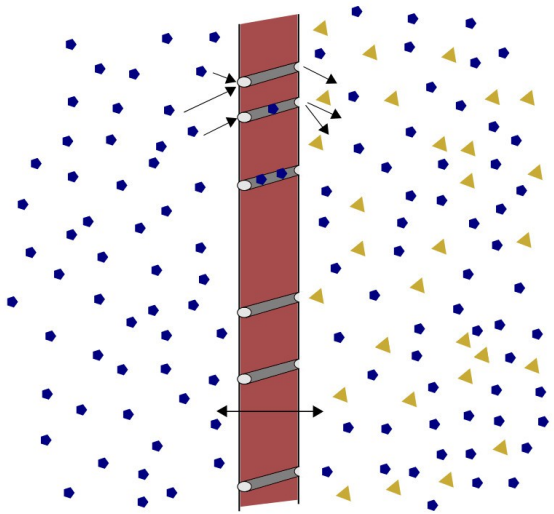
- Motivation
- Theoretical Background on forward osmosis (FO)
- Outline of original membraneFoam sources
- Modification of membraneFoam
  - OpenFoam 4.x adjustments
  - Automatic recognition of membrane feed side
  - Non-zero hydraulic pressure difference implementation
- Application tutorial
- Learning outcomes

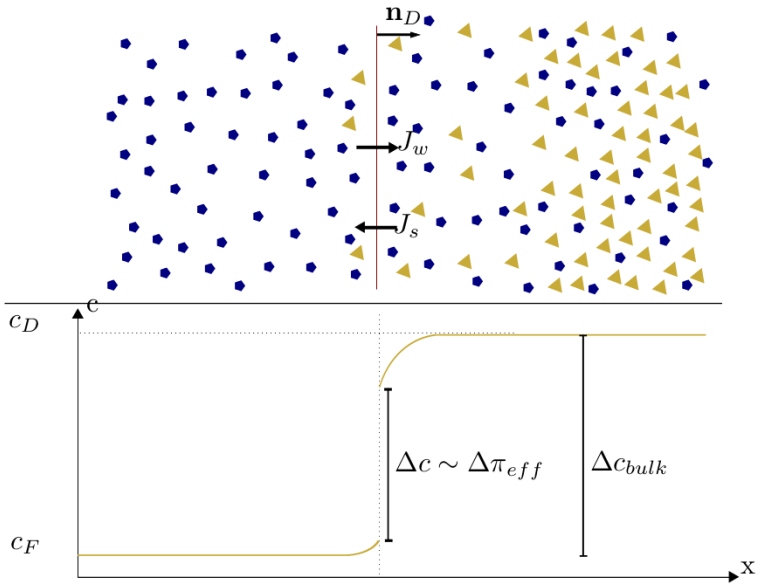
Motivation

- Detailed flow analysis of spiral-wound modules



Theoretical background:



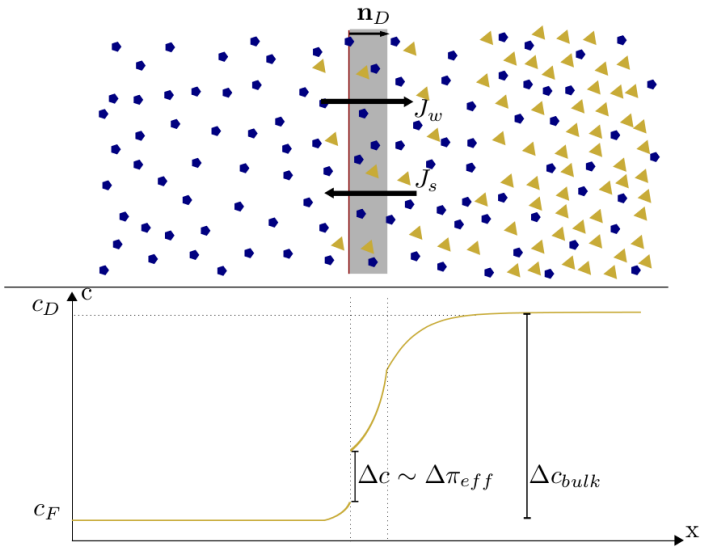


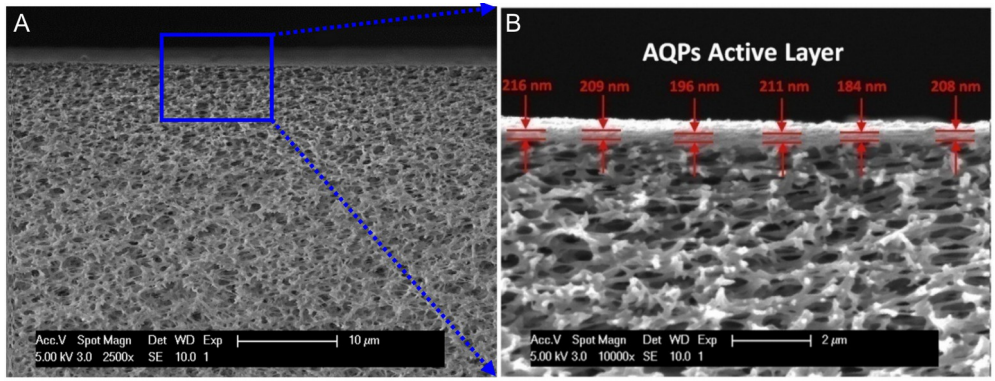
External concentration polarization (ECP) reduces the membrane performance due to incomplete solute mixing at the membrane.

Water flux: $$\mathbf{J}_W = A[\pi_D - \pi_F - (p_D - p_F)]\,\mathbf{n}_D = A[\Delta\pi - \Delta p]\,\mathbf{n}_D$$

Reverse Salt flux: $$\mathbf{J}_S = B[c_D - c_F]\,(-\mathbf{n}_D) = -B\Delta c\,\mathbf{n}_D$$

Internal concentration polarization (ICP) describes the solute accumulation within the porous support layer of the membrane.



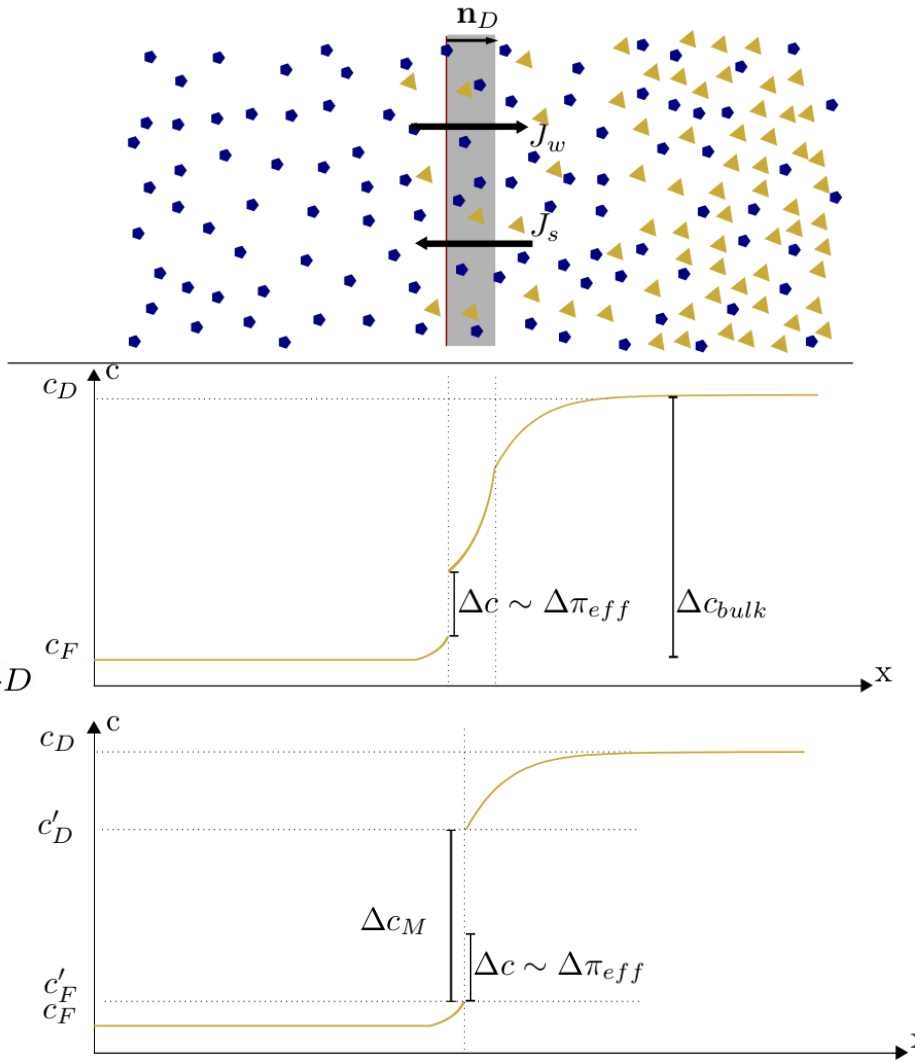


Original membraneFoam sources

The internal concentration polarization can be modelled through the equations below, allowing to not resolve the porous support in the simulations

$$\mathbf{J}_w = \frac{1}{K} ln \frac{B + A\pi'_D}{B + |\mathbf{J}_w| + A\pi'_F} \mathbf{n}_D$$

$$\mathbf{J}_w = A \left[\frac{\pi_F |\mathbf{J}_W| \left[\frac{c_D}{c_F} - exp(|\mathbf{J}_w| K) \right]}{(|\mathbf{J}_w| + B)\, exp(|\mathbf{J}_w| K) - B} - \Delta p \right] \mathbf{n}_D$$



Modification of membraneFoam sources - OpenFoam 4.x adjustments

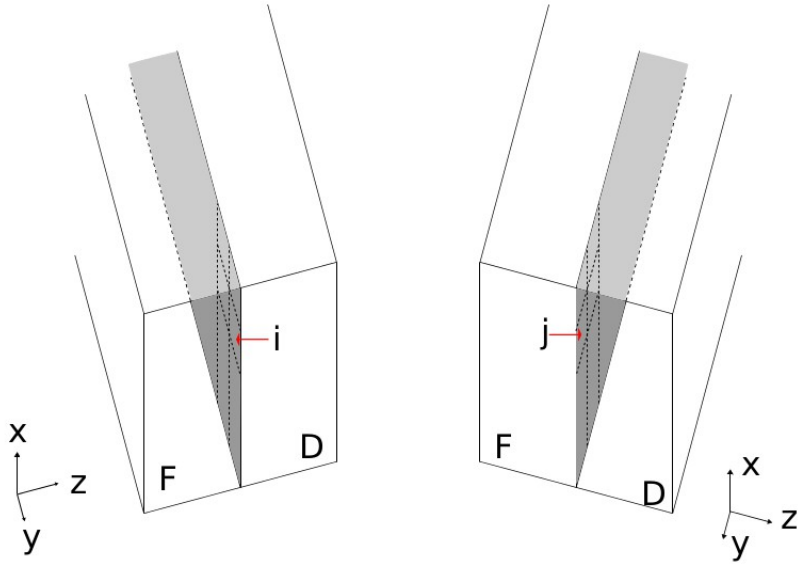
Only the solver simpleSaltTransport needed to be adjusted:

Non-constant wrapped objects are unwrapped using the .ref() function.

Modification of membraneFoam sources - Automatic recognition of membrane feed side

calcFaceMapping() is defining some membrane face index “j” to its opposing side “i”. The algorithm can then compare the concentrations and pressures on opposing sides and apply the flux function on the faces.

When the boundary was set to automatic feed side detection, the solvers crash at execution, where the object registry triggered the error. This was solved by relocating the solute object m_A in the createFields.H file.



Modification of membraneFoam sources - Non-zero hydraulic pressure difference

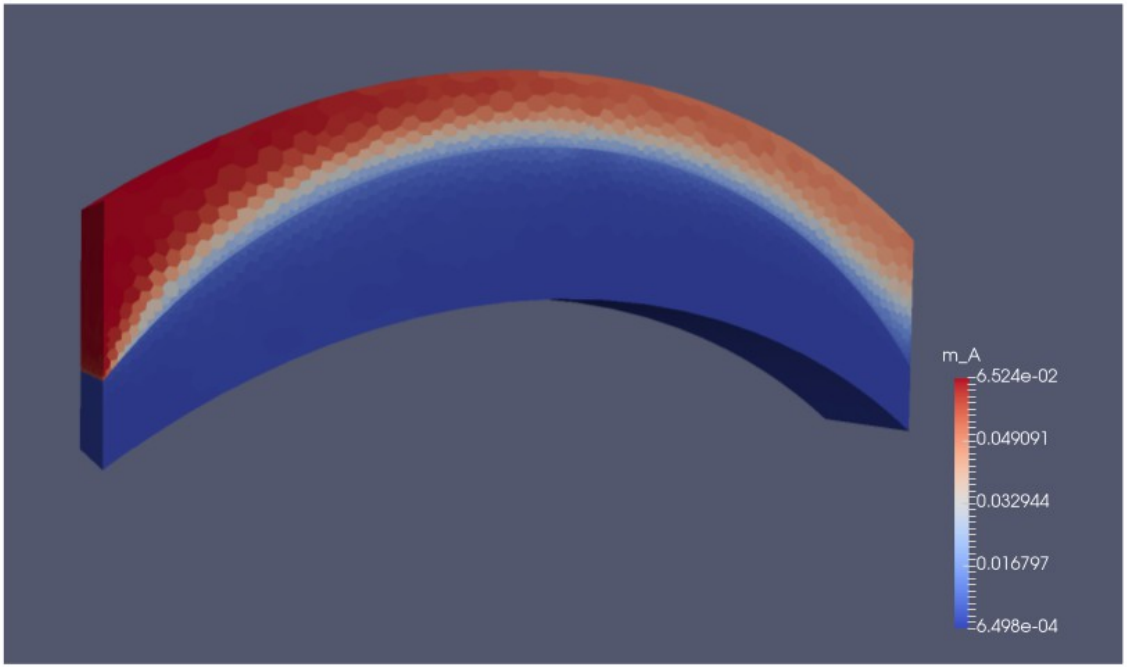
Implementation of the function below for the calculation of water flux.

$$\mathbf{J}_w = A \left[\frac{\pi_F |\mathbf{J}_W| \left[\frac{c_D}{c_F} - exp(|\mathbf{J}_w| K) \right]}{(|\mathbf{J}_w| + B)\, exp(|\mathbf{J}_w| K) - B} - \Delta p \right] \mathbf{n}_D$$

Application tutorial

The sources are found at:
https://github.com/MathiasGruber/MembraneFoam/tree/OF4

ParaFoam needs to be called with builtin option:



Learning outcomes

- Digging through OpenFoam sources, utilizing doxygen
- Interpreting Error messages
- Modification of existing OpenFoam files

Thank you for your attention!

Please contact me should you have any equations:
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