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Biofouling Potential of RO Membranes Including Micromixers

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Purpose

- Determine Biofouling of Innovative RO Membranes
  - Micromixers Added to Membrane Surface to Enhance Mixing
- Evaluate Biofouling Potential By
  - Performing Computational Fluid Dynamics (CFD) Simulations of Particle Deposition on Membrane Surface
- Compare to Biofouling Experimental Data

Background

- Net Deposition Rate of Particles Has Been Correlated With Biofouling by Kang et al. (2004) for Membranes (No Micromixers)
  - Permeate Flux a Dominant Factor
- CFD Simulations of Membrane Performance Including Permeate Flux Have Been Performed Using FLUENT by Webb (2007)
  - FLUENT Modified to Calculate Permeate and Salt Flux
- Perform CFD Simulations for Membranes Including Micromixers Including Particle Tracking and Particle-Membrane Interactions to Determine Particle Deposition on Membrane Surface

Models

Membrane

- 3-d Model of Membrane Test Cell
  - Feed Side Including Inlet and Outlet Legs
    - Includes Finer Mesh Near Membrane Surface to Capture Concentration Polarization
  - Permeate Side – Simplified Geometry
- Membrane Flux Model
  - Water Flux Through Membrane
    - Includes Osmotic Pressure (π) and Concentration (C) Polarization

$$J_w = A\,\rho_w\left(\Delta P - \Delta\pi\right)$$
$$\Delta P = P_u - P_d$$
$$\Delta\pi = \pi\left(C_u\right) - \pi\left(C_d\right)$$
$$\pi = K\,C$$

  - Salt Flux Through Membrane

$$J_s = B\left(C_u - C_d\right)$$

  - A and B are membrane constants, K is an osmotic pressure constant, u and d are upstream (feed) and downstream (permeate) values

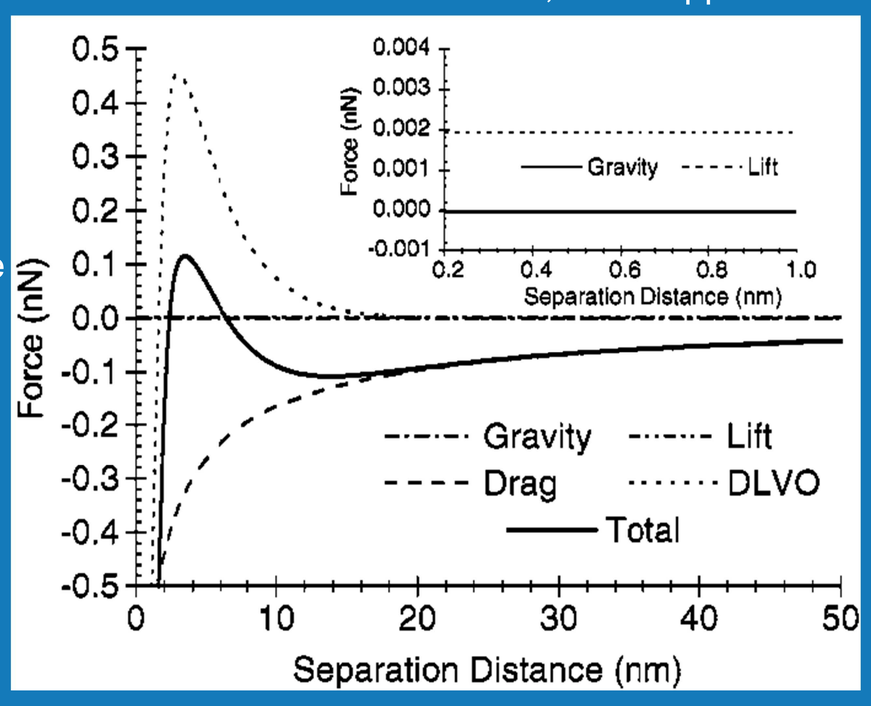
Models (cont.)

Particle Tracking

- Particle – Fluid Forces
  - Permeate Drag Force – Due to Permeate Flux
    - Becomes Large Attractive Force Close to Membrane
  - Gravitational Force
    - Due To Buoyancy – Negligible
  - Cross-Flow Lift
    - Small Magnitude
- Particle – Membrane Forces
  - DLVO (Derjaguin, Landau, Verwey, and Overbeek) Forces
    - van der Waals Force
    - Electrostatic Double Layer Force
- If Particle Reaches Membrane Surface, it is Trapped

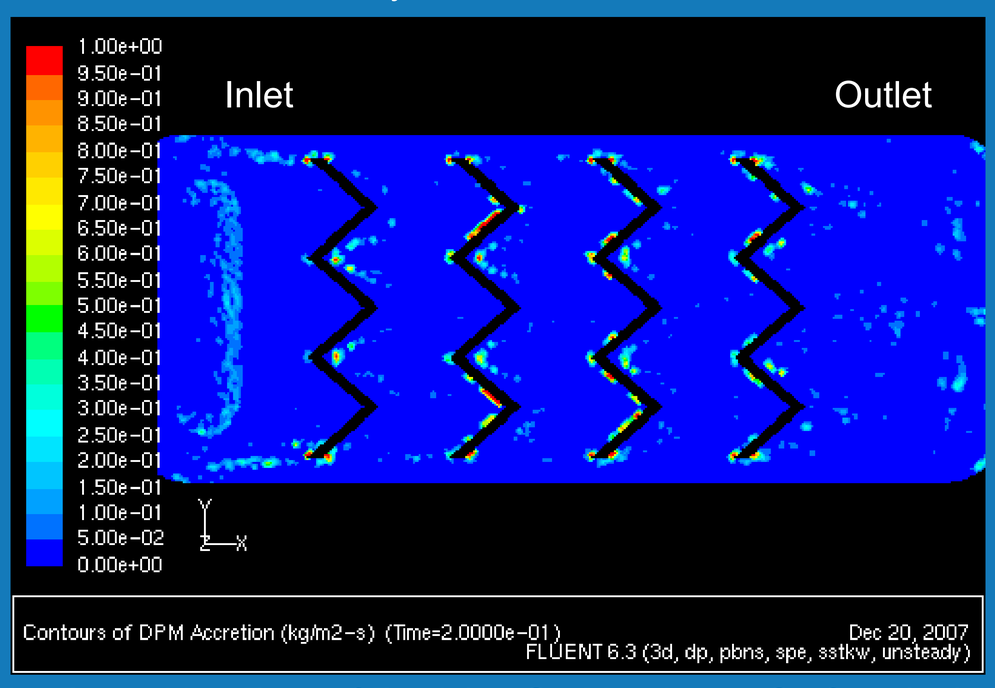
Repulsive

Attractive



Preliminary Results

- Net Deposition Rate of Particles On Membrane Surface Due To Particle-Fluid Forces Only



- Net Deposition Rate of Particles On Membrane Surface Including Particle-Membrane Forces Underway

Conclusions

- FLUENT is Being Used to Simulate Details of Fluid Flow Behavior in Membranes Including Water and Salt Flux Across Membrane and Concentration Polarization
- Particle Tracking in FLUENT is Being Used to Evaluate Biofouling Potential of Membranes Including Micromixers
- Preliminary Results Have Been Generated for Particle-Fluid Forces
- Simulations Are Ongoing Including Particle-Membrane Forces
- Results Will Be Compared to Experimental Data for Biofouling

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