Title

Concentration polarization modeling for high-pressure membranes with engineered surface features

Presenter

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Abstract

The goal of this research is to develop a computational framework to predict concentration polarization (CP) of patterned membranes designed for purification of saline or impaired waters. Extensive literature has studied the use of surface coatings on membranes to reduce fouling. More recently it has been proposed that the surface morphology can be modified (surface patterning) to give membranes fouling resistance, similar to what is seen in nature (i.e., shark skin, lotus leaves, etc.). CP, a mass transfer related phenomenon, is an important driver for fouling. Our research hypothesis is that certain pattern geometries can significantly reduce membrane fouling by reducing CP. The work presented here focuses on computational fluid dynamics (CFD) modeling to simulate different surface features and evaluate how fluid flows in the space above the membrane. The computational models were built to simulate membranes patterned in the lab with a silicone stamp. The stamp produced a variety of surface features including lines, circles, rectangles, triangles and some irregular shapes like crescents and jagged lines. The surface features varied in size from 250 nm to 1.024 mm with a pattern depth of 100 nm to 0.41 mm. Simulations evaluated the effects of velocity, pressure drop and concentration distribution on the fluid flow around the features. Velocity profiles showed that the surface features alter the fluid path, resulting in a lower velocity in between features, but a faster velocity on the elevated regions. Lower shear stress was observed in the valley region of the patterns, corresponding to higher concentration results. In most cases, patterns increase CP, but some large patterns cause vortices that induce local turbulence and shear stress, which disrupt CP layers. The best pattern discovered in the models could reduce CP by 21.6% compared to a flat membrane and increase flux by 1.48%.