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SUSTAINABLE EARTH RESOURCES ENGINEERING

Electrodialysis membrane desalination for water and wastewater processing: irregular attack angles of membrane spacers

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Abstract
Electrodialysis desalination is constructed with a number of anion exchange membranes (AEM), cation exchange membranes (CEM), anode, cathode, adjacent silicon gasket integrated membrane spacers, and inlet/outlet holes per cell. At the boundary among an ionic solution and an ion exchange membrane, concentration polarization develops. Spacers placed in between channel's walls function as stream baffles to increase turbulence, improve heat and mass transfer, diminish the laminar boundary layer, and lessen fouling problems. The current study offers a systematic review of membrane spacers, spacer-bulk attack angles, and irregular attack angles. Spacer-bulk attack angle is accountable for variations in the pattern and direction of stream which impact heat-mass transfer and concentration polarization. Irregular attack angles (e.g., 0°, 15°, 30°, 37°, 45°, 55°, 60°, 62°, 70°, 74°, 80°, 90°, 110°, 120°) in the present study were found to provide unique stream patterns due to the spacer's filaments being less or more transverse in respect to the primary solution direction, which may significantly alter heat transfer, mass transport, pressure drop, and overall flow dynamics. Spacer applies shear stress resulting by continuous stream tangent to the membrane exterior, which lessens polarization. In the end, 45° is concluded as the preferred attack angle that offers balanced rates of heat transfer, mass transport, and pressure drop throughout the feed channel while greatly lowering the rate of concentration polarization.

Keywords Concentration polarization · Membrane spacers · Pressure drop · Electrodialysis membrane desalination · Mass transfer · Boundary layer · Hydrodynamics · Hydraulic retention time · Computational fluid dynamics

Introduction

Electrodialysis membrane processes are significantly impacted by concentration polarization. Concentration polarization develops where an ion exchange membrane (IEM) meets an ionic solution, where the salt ions in the boundary layer are declining (Balster et al. 2009; Bai et al. 2018). Concentration polarization and heat polarization close to membrane sheets may be decreased by utilizing the optimum stack hydrodynamics.

It is crucial to utilize membrane spacers to reduce concentration polarization and heat polarization. The polarization rate was greatly impacted in all previous spacers that demonstrated increased mass transport performance in channels filled with membrane spacers compared to empty channels (Guizard and Rios 1996; Gurreri et al. 2014; He et al. 2016; Jalili et al. 2018; Sreedhar et al. 2018). The primary features of membrane spacers as turbulence promoters are roughness, porosity, open mesh area, thickness, drag force, angle between spacer's filaments, spacer-bulk attack angle, and pitch to height ratio (Chandra et al. 2019).

The attack angle of a spacer positioned among membranes has a substantial influence on the stream field and is essential for enhancing mass transfer (Hasani et al. 2009). When the main bulk collides with thin or thick strands at an attack angle, spacers can induce different multidirectional flow channeling (Da Costa et al. 1994). High turbulences can

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