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Investigation of Permeate Flux through DCMD Module by Inserting 3D-Printed Turbulence Promoters with Descending Hydraulic Diameters

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Abstract : The decline in permeate flux across membrane modules is attributed to the increase in temperature polarization resistance in flat-plate Direct Contact Membrane Distillation (DCMD) modules for pure water productivity. Researchers have discovered that this effect can be diminished by embedding turbulence promoters, which augment turbulence intensity at the cost of increased power consumption, thereby improving vapor permeate flux. The device performance of DCMD modules for permeate flux was further enhanced by shrinking the hydraulic diameters of inserted 3D-printed turbulence promoters as well as considering the energy consumption increment. The mass-balance formulation, based on the resistance-in-series model by energy conservation in one-dimensional governing equations, was developed theoretically and conducted experimentally on a flat-plate polytetrafluoroethylene/polypropylene (PTFE/PP) membrane module to predict permeate flux and temperature distributions. An economic analysis was also performed, weighing both permeate flux improvement and power consumption increment on modules with promoter-filled channels by different array configurations and geometric shapes of turbulence promoters. Results showed that the ratio of permeate flux improvement to energy consumption increment in descending hydraulic-diameter modules is higher than in uniform hydraulic-diameter modules. Theoretical predictions and experimental results exhibited a great accomplishment to considerably achieve permeate flux enhancement such as a new design of the DCMD module with inserting 3D-printed turbulence promoters. Additionally, the Nusselt number for the water vapor transferring membrane module with inserted 3D-printed turbulence promoters was generalized into a simplified expression to predict the heat transfer coefficient and permeate flux as well.

Keywords : permeate flux, Nusselt number, DCMD module, temperature polarization, hydraulic diameters
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