Reducing scaling proneness in large-scale MD modules using feed redistribution strategies

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Abstract:

Membrane distillation (MD) stands among the most promising technologies for the treatment of high salinity feeds. However, MD scale-up remains challenging due to temperature polarization, an inherent phenomenon that drastically hinders the process translation beyond laboratory prototypes. Using a fully coupled computational fluids dynamics and pore-scale calculation approach, it is shown that the decrease in average permeate flux in a DCMD configuration scales with the ratio of module length to inlet flow rate. Moreover, analysis of the permeate flux distribution along the membrane in a cross flow design, reveals that the membrane active area is underused. As such, the maximum productivity is reduced to a short portion at the inlet of the module, which suggests a redistribution of the feed and permeate along their respective channels. This redistribution can be achieved using showerhead-like perforated plates as top walls of the feed and permeate channels. Calculations show that an optimization of the size, spacing and distribution of the holes along the channels can lead to 50% enhancement of the module productivity. In order to assess the scaling proneness during the treatment of high salinity feeds, Pitzer's equations are solved simultaneously with the coupled CFD-pore scale equations. The model is calibrated using in-house experiments performed for the treatment of concentrated brines. The estimation of the feed ionic strength, the ions activity coefficients and salts solubility product allows the calculation of the degree of saturation of the feed with respect to different salts and assess the relative proneness to scaling as a function of module size. Results reveal that scaling limits the scale-up of MD modules and that feed redistribution could be a key solution to not only reduce the temperature polarization but also alleviate the scaling by refreshing the solution along the feed channel.

Keywords: Membrane distillation, scale-up procedures, feed redistribution, scaling proneness, modules design.