Optimization of Ladder-type Spacers for Nanofiltration and Reverse Osmosis Spiral-wound Modules by Computational Fluid Dynamics

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Abstract
The velocity and solute concentration distribution in the feed channel of a spiral wound module with ladder-type spacers is investigated by computational fluid dynamics (CFD) for laminar flow and permeation of sucrose aqueous solution. The spiral wound module feed channel was approximated by a rectangular channel filled with ladder-type spacers that have the transverse filaments adjacent to a single membrane wall. The momentum and mass transport equations together with the appropriate boundary conditions are solved numerically by the control volume formulation. The numerical predictions were performed for Reynolds numbers of Re = 50, 100 and 200, \(P_f = p_f/h = 0.25, 0.5\) and 0.75 and \(L_f = l_f/h = 1.9, 3.8\) and 5.7 — where \(h\) is the channel height, \(p_f\) is the transverse filament height and \(l_f\) is the distance between neighbor filaments axis. The numerical results show that the flow is dominated by a recirculation region downstream of each transverse filament and that there are no recirculation regions in the upper part of the channel. Three flow structures were identified: for low values of \(Re\) and \(P_f\) and high values of \(L_f\) the recirculation region does not fill the inter-filaments space; for high values of \(Re\) and \(P_f\) and low values of \(L_f\) the recirculation regions fills the inter-filaments space; and for \(P_f = 0.75\), a secondary recirculation region can develop inside the main one. The numerical results show that the spacer optimal values of \(P_f = 0.25\) and \(L_f = 5.7\) minimize both the concentration polarization and the longitudinal pressure drop.

Keywords: computational fluid dynamics, spiral-wound modules, reverse osmosis

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