CFD simulation of Electrodialysis channels equipped with profiled membranes

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Electrodialysis (ED) is a membrane-based electrochemical process that remove ions from a solution. The main use of ED is for the production of drinking water by brackish water desalination, but there are several other applications. ED is characterized by the coexistence and the interaction of different physical phenomena that affect the stack performance. Among them, fluid dynamics and mass transport are crucial: concentration polarization affects the limiting current density and the non-Ohmic voltage drop due to the chemical potential difference between the two solutions; pressure drop affects the pumping power consumption. Moreover, the total energy consumption depends also on the Ohmic voltage drop. Therefore, the channel configuration is a major feature of an electrodialyser. In this regard, profiled membranes can improve the process efficiency by avoiding the use of non-conductive and relatively expensive spacers and by increasing the active area. Furthermore, simple geometries of profiles that alter only slightly the flow can reduce pressure drops.

In the present work, computational fluid dynamics simulations were carried out in order to predict flow and mass transfer in profiled-membrane channels for ED applications. Pillar profiles of square section were studied and the pitch to channel height ratio and the Reynolds number were let to vary. The Unit Cell approach was adopted by solving Navier-Stokes and continuity equations along with a convective-diffusive transport equation in the periodic domain of the cell pair.

Simulation results showed that the present pillar profiled-membrane channels are characterized by pressure drops being much closer to those in an empty channel rather than in a spacer-filled channel. On the other hand, velocity and concentration fields exhibited calm regions that result in a poor degree of mixing (low Sherwood numbers); as a consequence, mixing was favoured with respect to the empty channel only at Reynolds numbers higher than ~7-20.

Keywords: Electrodialysis, Profiled membrane, CFD, Concentration polarization, Pressure drop.

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