Integrated modelling of membrane deformation, fluid dynamics and mass transfer in electromembrane processes

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In recent years, water and energy supply issues have drawn the attention of the scientific community to electromembrane processes. Electrodialysis (ED) and Reverse Electrodialysis (RED) are two of the most attractive electromembrane technologies for water desalination and electric energy production from salinity gradients, respectively. In order to gain an important place in the industrial market, technological challenges on various aspects are involved in the optimization of these processes. In this context, profiled membranes exhibit interesting performance. However, the mechanical behavior of the membranes and its interaction with fluid dynamics has been poorly investigated so far.

In membrane-based processes, a trans-membrane pressure (*TMP*) between the different solutions flowing through a module may be a design feature or may arise for various reasons (e.g. flow arrangement, differences in physical properties). This may lead to a local deflection of membranes due to their low mechanical stiffness. As a result, the channel geometry may be modified affecting flow and mass transfer characteristics.

In this work, we developed an integrated model for the numerical simulation of local mechanical deformation and of fluid dynamics and associated mass transport phenomena inside deformed channels. Profiled membranes with Round Pillars were simulated under typical RED\ED working conditions. Membranes were assumed to be with perfectly linear elastic behaviour. 3-D simulations of a couple of membranes and of the interposed fluid were conducted by the unit cell approach (periodic domain). The *Ansys Mechanical 18* (*Workbench*) and the *Ansys CFX 18* software was used.

[illegible] itions by varying the *TMP* of 0.1 bar steps from -0.4 to +0.4 bar. Then, CFD simulations of the deformed channels were performed.

The influence of TMP was to increase friction under compression conditions (up to ~2.2 times) and to reduce it under expansion conditions (i.e. up to ~60%). Overall, compression enhanced mass transfer and expansion reduced it, but with smaller and more complex effects than on friction.

Channel deformations affect largely fluid dynamics and mass transfer characteristics. Even mild trans-membrane pressures may produce significant variations in the overall process performance. Results will be implemented in a novel higher-scale simulation tool for studying the distribution of flow in whole channels.

Keywords: Ion exchange membrane; electrodialysis; reverse electrodialysis; membrane deflection; fluid-structure interaction; CFD.

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