such energy source. In PRO water from a low salinity feed solution permeates through an osmotic membrane into a pressurized high salinity draw solution, thus naturally increasing the pressure energy of the pressurized stream. Power is eventually obtained from the pressurized stream adopting water turbines or using it in pressure exchanger/turbo-chargers for pressurizing a different stream, thus saving electrical/mechanical energy.A part from the typical source of salinity gradients, namely river water and sea water, more and more interest has been raised recently towards the use of non conventional saline solutions, such as waters from a waste-water treatment plant or desalination brines. However, the main limitation in the process still remains the performances of osmotic membranes in terms of water fluxes, mechanical robustness and resistance against fouling phenomena.

Aim of this work has been to investigate the feasibility of PRO technology for power generation from saline streams originated by different water treatments plants, namely brine from a thermal desalination plant and fresh water from a sewage treatment plant.Two lab-scale test-rigs were designed and built in order to assess the performances of several osmotic membranes, under various operating conditions.The first one exhibits a conventional planar geometry cell, operated under atmospheric pressure (forward osmosis or depressurized-PRO operations).The second test-rig is comprised of a customized cylindrical membrane module, able to mechanically support the osmotic membrane.The newly developed module allows for controlled contact between the two solutions under pressurized operating conditions.Artificial solutions at different salt concentration and two real saline solutions were adopted for the experimental campaign. Results have highlighted the differences between membranes and module configurations. Long-run tests have also indicated a different decline in performance when adopting real solutions rather than artificial ones, providing useful indications on how fouling phenomena can affect the membrane behavior and highlighting the importance of counteracting them by different operating strategies.

Keywords: Salinity gradient power, PRO, Forward osmosis, Brine, Wastewater, Energy recovery

263

Modelling the transient behaviour of a MED-TVC plant for coupling with CSP

A. Cipollina[a], M. Agnello[a], A. Piacentino[b], A. Tamburini[a], G. Micale[a]*

[a]*Dipartimento di Ingegneria Chimica, Gestionale, Informatica, Meccanica (DICGIM),*
[b]*Dipartimento di Energia, Ingegneria dell'Informazione e Modelli Matematici (DEIM),*
Università di Palermo (UNIPA), – viale delle Scienze Ed.6, 90128 Palermo, Italy
**e-mail: giorgiod.maria.micale@unipa.it*

Thermal vapour compression multi-effect distillation (MED-TVC) is among the most popular desalination processes for the coupling with solar energy application, especially when solar thermal energy is concerned. Several models have been developed so far and presented in the open literature, though most of them can not simulate a number of secondary phenomena, which can have significant importance in the simulation of transient behaviour of the MED unit. In this paper a dynamic model for the MED-TVC process has been developed, and validated by a comparison with data from a real plant situated in Trapani, Italy, composed by 12 effects with parallel-feed configuration and equipped with a medium-pressure steam vapour ejector. The model was implemented using gPROMS®, a powerful dynamic modelling platform for process simulation. The transient comportment of the overall process is modelled by a set of algebraic and ordinary differential equations based on mass and energy balances, thermodynamic equilibria and constitutive equations. The model is developed through a hierarchical structure, with models for the single effects, the thermo-ejector, pre-heaters, etc. and a higher-level model for the overall plant. The model is able to predict the behaviour of the unit in the presence of non-condensable gases, thus carefully simulating all the main physical phenomena happening in transient operations of the MED plant. The implemented model was coupled with a dynamic model simulating the transient behaviour of a molten-salts Concentrated Solar Power plant, simulating transitory operations of the co-generation plant for a period of one month, characterised by the real oscillatory trend of solar irradiation. Results highlights the main issues related to the operation under transitory conditions and indicate the most effective strategies for controlling and optimised solar-powered co-generation plants.

Keywords: Process modeling, gPROMS, Dynamic simulation, MED, TVC, CSP, Molten salts

264

Pressure drop in woven-spacer-filled channels for reverse electrodialysis: CFD prediction and experimental validation

L. Gurreri, A. Tamburini*, A. Cipollina, G. Micale, M. Ciofalo

Dipartimento di Ingegneria Chimica, Gestionale, Informatica, Meccanica (DICGIM), Università di Palermo (UNIPA) – viale delle Scienze Ed.6, 90128 Palermo, Italy.
**Corresponding author: alessandro.tamburini@unipa.it*

Reverse electrodialysis (RED) is a promising technology for electric power generation by the chemical potential difference of two salt solutions within a stack equipped by selective ion-exchange membranes (salinity gradient energy). Mechanical energy is required for pumping the feed solutions, which can reduce dramatically the net power output. Pressure drops, affecting pumping power, are influenced by stack geometry, flow rate and feeds properties. Moreover they can be identified as pressure drops distributed along the channels and those localized in the distribution/collection manifolds. Net spacers are usually adopted as mechanical support and mixing promoters, but exhibit high pressure drops compared to the empty channel. Of course, spacer features have a significant impact on the performance.

In this work computational fluid dynamics (CFD) simulations of spacer-filled channels for RED were carried out in parallel with an experimental campaign focused on the collection of data for model validation. Woven spacers 280-480 μm thick were investigated at the flow rates typical of RED channels. The construction of the computational domain was based on measurements made by optical microscopy and micrometer; also, the compression of filaments was taken into account in order to reproduce realistic geometries in the simulations. Fully developed flow conditions were assumed, thus periodic boundary conditions were adopted (unit cell approach). The computational domain was discretized by hybrid grids mainly composed by hexahedral volumes and with tetrahedral volumes near the filaments. The sensitivity analysis of the results to the discretization degree was tested preliminarily. The experimental apparatus consists of a mono-channel stack in the classical plate-and-frame geometry. Pressure drops were measured with and without the spacer, in order to quantify the effect of inlet-outlet channel and identify the distributed pressure drops due to the woven nets.

Experimental results showed that the distributed pressure drop along the spacer-filled channel