tages and disadvantages of the three different scenarios are highlighted in terms of performance enhancement for the regeneration stage as well as in terms of effect of organic solvents presence within the RED unit.

Keywords: RED, SGP heat engine, Waste heat, Evaporation, Organic mixtures.

Acknowledgements

This work has been performed within the RED-Heat-to-Power project (Conversion of Low Grade Heat to Power through closed loop Reverse Electro-Dialysis) - Horizon 2020 programme, Grant Agreement n. 640667.

487

Heat-transfer performance comparison between overlapped and woven spacers for membrane distillation

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

**E-mail: alessandro.tamburini@unipa.it*

Sustainable production of fresh water from seawater desalination is a problem of crucial importance nowadays. Recently, some desalination technologies are taking advantage from the coupling with renewable resources. Among emerging technologies, membrane distillation (MD) is considered as one of the most promising as it can be easily powered by solar thermal energy or waste-heat.

As an emerging technology, efforts are required to optimize MD unit geometry and operating conditions in order to reduce fresh water production specific cost.

Temperature polarization phenomenon is a well-known detrimental effect for the MD process. Spacers are traditionally used to enhance mixing and shrink temperature boundary layers yet yielding higher pressure-losses. The present work is devoted to testing the performance of two different two-layer net-spacers: overlapped and woven. Investigations were carried out by both experiments and computational fluid dynamics (CFD) simulations at different Reynolds numbers ranging from creeping to turbulent flow regime. Experiments (intermediate to high Re) were performed via a novel experimental technique making use of thermochromic liquid crystals and digital image analysis. Computational data (low to intermediate Re) were obtained via steady state (low Re) and direct numerical simulations (intermediate Re), adopting the unit cell approach. A good agreement between experiments and CFD data was found in the range of superposition.

Results showed that woven spacers guarantee a better mixing than overlapped ones especially in the low-intermediate range of Re thus resulting into a higher Nusselt number. On the other hand, the less disturbed flow field induced by the overlapped wires was found to give raise to lower pumping losses.

488

Multi-physical modelling of reverse electrodialysis

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

Dipartimento di Ingegneria Chimica, Gestionale, Informatica, Meccanica (DICGIM), Università degli Studi di Palermo (UNIPA) – viale delle Scienze Ed.6, 90128 Palermo, Italy

**E-mail: giorgiod.maria.micale@unipa.it*

Energy extraction from salinity gradients (salinity gradient power, SGP) represents a novel and valuable renewable energy source. Among the existing SGP technologies, reverse electrodialysis (RED) is the oldest and one of the most promising. RED is a membrane-based electrochemical process that directly converts the salinity gradient energy into electric current. More precisely, in a RED unit two solutions at different concentration flow in two series of alternated channels, which are formed by piling two alternated series of cation and anion exchange membranes (CEMs and AEMs, respectively). The chemical potential difference between the two solutions generates an electric potential difference over each membrane along with a selective transport of cations (across CEMs) and anions (across AEMs) from each concentrate channel towards the two contiguous dilute ones. Eventually, the so generated ionic current is converted by redox reactions into an electric current in the two electrode compartments closing the stack.

RED is characterized by a number of different physical phenomena, which should be properly modelled in order to drive the process design and optimization. In this regard, this work presents a novel approach for multi-physical modelling of the entire RED process. A single 2-D cell pair (encompassing two membranes and two feed channels) is the identified process repeating unit, coinciding with the computational domain investigated. In order to fully cover the phenomenological complexity of the operation of a RED unit, a number of different physical models were implemented and interconnected each other. In particular: (i) Navier–Stokes and continuity equations were solved for fluid dynamics modelling; (ii) Nernst–Plank equation was used for ion mass transfer; (iii) local electroneutrality condition was assumed everywhere, taking also into account the fixed charges concentration within the membranes. At membrane-solution interfaces: (iv) Donnan exclusion theory was applied to simulate voltage jump; (v) partition coefficients were adopted to simulate concentration jump. Finally, the model is completed by (vi) algebraic equations for the calculation of stack potential, current density and gross / net power density in a stack of any given number of cell pairs, by taking into account also the electrode compartments resistance and the external load variation.

As model outputs, the distributions of velocity, pressure, concentrations, fluxes and potential in the overall domain were obtained, and the values of gross and net power density were computed. Different membrane/channel configurations were investigated, including flat membranes, either with or without non-conductive spacers, and profiled membranes. Moreover, the influence of the feeds concentration was evaluated. The model developed appears to be a promising tool for the optimization of RED units design and operation.

Keywords: Reverse electrodialysis, Multi-physics, Finite elements, Profiled membranes, Spacers.