for the RED and MED systems have been developed in order to investigate the efficiency of the integrated system. The RED process is described by a hierarchical model, where the low level is a distributed parameter model discretized along the length of the membranes, and the high level consists of the electrical equivalent circuit of the entire stack. The MED model is mainly based on mass and energy balances applied over the different components of the unit, together with the heat transfer equations associated with the heat exchangers. The overall model implemented in the engineering equation solver (EES) software, takes into account all the main phenomena involved in process and after validation proves to be reliable. Also, both working fluids have been characterized by their thermophysical and transport properties.

The influence of the main operating conditions (i.e. solutions concentration and velocity) and design features (stack aspect ratio) has been assessed, identifying the most advantageous scenarios. The effect of new generations of high performing membranes has been considered. Results show the great potential of this novel and promising power conversion technology, which has a large room for improvement if high-performing membranes and suitable artificial salt solutions are employed.

Keywords: Salinity gradient power (SGP), Reverse electrodialysis (RED), Multi-effect distillation (MED), Reverse electrodialysis heat engine (RED-HE), Exergy efficiency

Acknowledgment

This work was performed within the RED-Heat-to-Power project (Conversion of Low Grade Heat to Power through closed loop Reverse Electro-Dialysis), funded by EU within the H2020 research & innovation programme, grant agreement n. 640667. www.red-heat-to-power.eu

231

Modeling and design of membrane process recovery of HCl and metals from pickling solutions

S. Randazzo, A. Culcasi, R. Gueccia, A. Cipollina, G. Micale

Dipartimento di Ingegneria Chimica, Gestionale, Informatica, Meccanica, Università di Palermo
Viale delle Scienze ed.6, 90128 Palermo, Italy
**Corresponding Author. E-mail: serena.randazzo@unipa.it*

Hydrochloric acid pickling is one of the key steps in the hot-dip galvanizing process. It is a process widely used as a chemical pre-treatment method for cleaning, where metal surfaces with oxides are immersed into an acid solution. During the pickling process, the acid concentration decreases with time while the metal is accumulated. Thus, the efficiency of the pickling solution decreases and fresh solution must be used. Continuous regeneration of pickling solutions enhances pickling rate and process performance, but also minimises industrial wastewater disposal and chemicals consumption. The recovery and recycling process of valuable substances (e.g. acid and metals) can be accomplished by coupling diffusion dialysis (DD) and membrane distillation (MD) technologies [1,2].

The integrated process is based on a recovery of more than 80% of the free acid exiting from the pickling bath by passing through a selective anionic exchange membrane (in the DD), and then, its concentration by water evaporation through a hydrophobic membrane (in the MD) in order to be recycled in the pickling tank. The outlet stream from the diffusion dialysis, concentrated of metal salts, is fed to a reactive precipitation unit to recover iron as valuable product (iron hydroxide) by adding an alkaline reactant, whereas zinc salt is kept in the solution to be reused.

In the present work, a steady state process simulator for the integrated process has been developed, in order to analyze and predict performances of a small pilot-scale unit to be installed and operated within a hot-dip galvanizing plant. A parametric analysis of the model is performed varying hydrochloric acid and iron concentration in the pickling tank. In this way, usual operations of withdrawing of partially exhausted solutions and refilling with fresh acid is avoided allowing to continuously operating under the optimal pickling conditions.

Keywords: Process simulator; Hydrochloric acid recovery; Diffusion dialysis; Membrane distillation

Acknowledgments

This work has been funded by EU within the ReWaCEM project (Resource recovery from industrial waste water by cutting edge membrane technologies)–Horizon 2020 program, Grant Agreement no. 723729. www.rewacem.eu

References

[1] M. Tomaszewska et al., Recovery of hydrochloric acid from metal pickling solutions by membrane distillation, Separation and Purification Technology 22-23 (2001), 591-600.
[2] J. Luo et al., Diffusion dialysis-concept, principle and applications, Journal of Membrane Science, 366 (2011) 1-16.

232

Experimental investigation and modelling for sulphuric acid recovery by diffusion dialysis

S. Randazzo, A. Ruiz Aguirre, J. Lopez Rodriguez, R. Gueccia, A. Cipollina, G. Micale

Dipartimento dell'Innovazione Industriale e Digitale, Università di Palermo
Viale delle Scienze ed.6, 90128 Palermo, Italy.
**Corresponding Author. E-mail: serena.randazzo@unipa.it*

Sulphuric acid is known to be one of the key inorganic acid and has been widely used in chemical reaction and metal industries for surface treatments as in the copper electroplating process. During these processes, large amounts of waste sulphuric acid solution are generally generated, containing high concentrations of metals and acid. The possibility of recover and reuse the sulphuric acid in the process could avoid environmental contamination and reduce costs of the disposal. Among several separation methods, diffusion dialysis (DD) is becoming more and more attractive thanks to the recent important advances in ion exchange membranes (IEMs) field and because of its clean nature and operational simplicity, low installation and operating costs and low energy consumption [1,2].

In the present work, two single-cell diffusion dialysis modules, equipped with commercial anion exchange membranes, with different dimensions, were employed. The first consisted in a laboratory-scale DD unit (10 x 10 cm^2) operated in a batch configuration to study the effect of process parameters on the efficiency of H_2SO_4 recovery. The latter consisted in a large-scale DD unit (80cm long) operated in a continuous configuration to simulate the process operation at the industrial scale. Acid recovery has been evaluated at different operative conditions. In both the cases, the effect of the presence of copper salt on the acid recovery was also evaluated.