Simulation of DCMD shell and hollow fibre bundle module

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Desalination technologies can help mitigating the water scarcity problem facing humankind. In this work we consider the Direct Contact Membrane Distillation (DCMD) concept for desalination, where the feed and the permeate flows are separated by a hydrophobic porous membrane. We employ the Dusty Gas Model to describe the vapour diffusion through the membrane pores [1]. A sustained heat flow is the mechanism responsible for maintaining the required temperature difference between the two sides. The present model accounts for all the relevant heat transfer processes. These include convective heat transfer, latent heat transport by the vapour crossing the membrane pores, and conductive heat transfer through the membrane matrix. The DCMD module is a cylindrical shell, with internal radius R_s, which is occupied by n_f hollow fibres. A detailed 3D modelling of the flow inside the shell would render the analysis computationally expensive. Thus, we adopted a simplified one-dimensional model based on defining an equivalent channel for the shell flow surrounding a single representative hollow fibre, as shown in Figure 1.

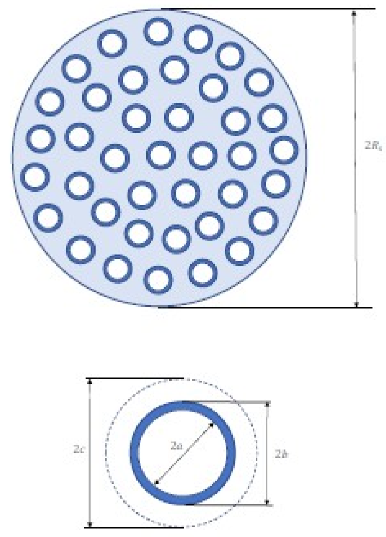

Figure 1. Shell cross section (top) and equivalent channel (bottom).

Analytical solutions of the mass and heat transfer across the membrane are combined with finite volume discretized equations describing energy and mass conservation for the feed and permeate streams. An iterative scheme is devised to solve the model equations and determining the flow and temperature variables inside the DCMD module. The computational model predictions show good agreement with experimental data available in the literature as shown in Figure 2 and Figure 3.

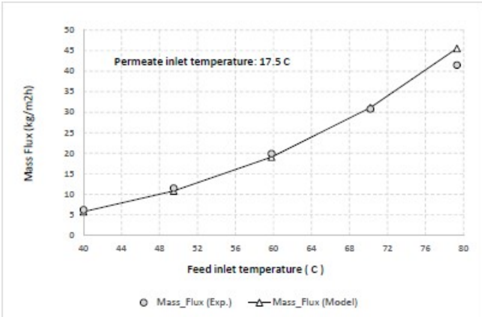

Figure 2. The effect of feed temperature on mass flux. Comparison between the present model and experimental results from [2].

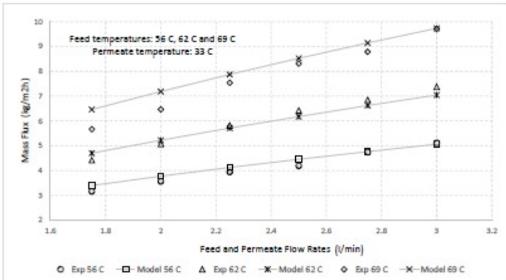

Figure 3. Mass flux at different temperatures and flowrates. Comparison between the present model and experimental results from [3].

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