Understanding Flooding Phenomena in Mini-Channel of Proton Exchane Membrane Fuel Cells

Philippine de Crevoisier Gouy de Bellocq-Feuquieres, Marc Prat, Joel Pauchet, Jean-Philippe Poirot

Understanding Flooding Phenomena in Mini-Channel of Proton Exchane Membrane Fuel Cells

Philippine de Crevoisier[1], Marc Prat[2,3], Joël Pauchet[1], Jean-Philippe Poirot-Crouvezier[1]

[1] CEA, LITEN, LCPEM, Laboratory of Fuel Cell Components, Electrolysers and Modeling, 17 rue des Martyrs, 38054 Grenoble, France

[2] Université de Toulouse, INPT, UPS, IMFT, Avenue Camille Soula 31400, Toulouse, France

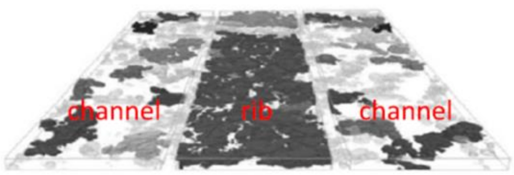
[3] CNRS, IMFT, 31400 Toulouse, France

Corresponding e-mail : philippine.decrevoisier@cea.fr

Proper management of the water produced in the Proton Exchange Membrane Fuel Cell (PEMFC) is necessary to improve the system performance and lifetime. Indeed, the accumulation of liquid water in the GDL (Gas Diffusion Layer) or in the gas supply channels can reduce the supply of reactants to the active layer. The development of PEMFCs with more compact cells, with thinner channels and reaching higher current densities will make this system even more sensitive to flooding. On the contrary, the absence of humidification in a cell will cause a decrease in the proton conductivity of the ionomers and a degradation of the materials.

In order to improve the predictability of the flooding of PEMFCs, and to better understand the liquid water transport phenomena in the cell, a channel-rib pore network model is under development. It relies on previous work done at CEA-LITEN and CNRS/IMFT[1], [2]. This model has been validated against experimental data, as shown in Figure 1. It will eventually allow predicting the behaviour of the system locally as a function of the local operating conditions and local properties of the gas diffusion layer. This model, once coupled to a second model developed at the scale of a cell, which accounts for heterogeneities between inlet and outlet of the cell [3], will allow a more efficient prediction of water distribution in the cell and especially the occurrence of flooding. This coupling is necessary since even though the cell model has already shown good agreement with experimental data for some operating conditions as seen in Figure 2, it still needs more accuracy in other cases, for example at higher current density (Figure 3).

A first step towards the objective of a coupled model is to obtain for given operating conditions effective transport parameters at the rib-channel scale, which can be used as inputs to the cell model. A simple transport model to represent the transport of species in the GDL is Fick's law, which allows to consider a binary mixture (vapour and oxygen in our case) whose species would only be subject to diffusion. However, there is a pressure gradient across the GDL, imposed by the difference between the flow of O_2 consumed and the flow of water vapour produced. Of course, this gradient can be assumed small outside of flooding conditions. However, in the case where the GDL is highly saturated with water, the pressure gradient within the GDL can increase. The convective fluxes due to the pressure gradient will then be higher. Therefore, the gas transport within the GDL will be studied mainly by two models: a binary diffusion model based on Fick's law, and a diffusion/convection model based on Young and Todd's model[4]. They will be compared to define if a simple and low computational time consuming model can be sufficient for our study or not.



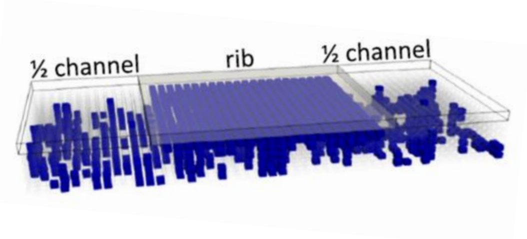


Figure 1. Comparison between experimental measurement [5] of water distribution by X-ray tomography (left) and simulated result (right) [1] at same operating conditions (80°C, 0.75A/cm², 100%RH in channel)

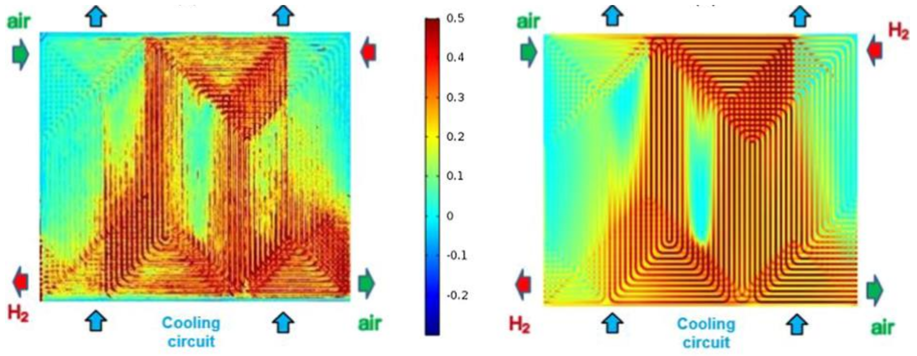


Figure 2. Comparison between measured (left) and simulated (right) total water thickness at 0.25A/cm² and 64°C at cell scale [3].

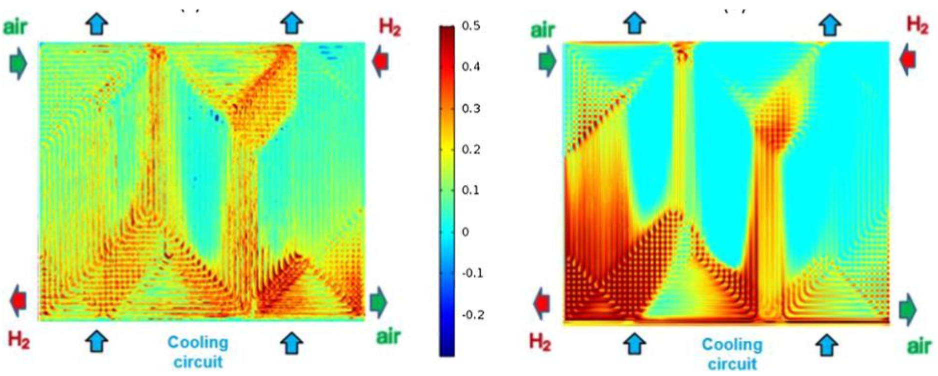


Figure 3. Comparison between measured (left) and simulated (right) total water thickness at 1A/cm² and 59°C at cell scale [3].

[1] P. Carrere and M. Prat, 'Liquid water in cathode gas diffusion layers of PEM fuel cells: Identification of various pore filling regimes from pore network simulations', *International Journal of Heat and Mass Transfer*, vol. 129, pp. 1043–1056, Feb. 2019, doi: 10.1016/j.ijheatmasstransfer.2018.10.004.

[2] N. Belgacem, M. Prat, and J. Pauchet, 'Coupled continuum and condensation–evaporation pore network model of the cathode in polymer-electrolyte fuel cell', *International Journal of Hydrogen Energy*, vol. 42, no. 12, pp. 8150–8165, Mar. 2017, doi: 10.1016/j.ijhydene.2017.01.184.

[3] E. Tardy et al., 'Investigation of liquid water heterogeneities in large area PEM fuel cells using a pseudo-3D multiphysics model', *International Journal of Heat and Mass Transfer*, p. 15, 2019.

[4] J. B. Young and B. Todd, 'Modelling of multi-component gas flows in capillaries and porous solids', *International Journal of Heat and Mass Transfer*, vol. 48, no. 25–26, pp. 5338–5353, Dec. 2005, doi: 10.1016/j.ijheatmasstransfer.2005.07.034.

[5] J. Eller, J. Roth, F. Marone, M. Stampanoni, and F. N. Büchi, 'Operando Properties of Gas Diffusion Layers: Saturation and Liquid Permeability', *J. Electrochem. Soc.*, vol. 164, no. 2, pp. F115–F126, 2017, doi: 10.1149/2.0881702jes.