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Investigation of Liquid Water Heterogeneities in Large Area PEM Fuel Cells using a Two-Phase Flow Multiphysics Model

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The Proton Exchange Membrane Fuel Cell (PEMFC) is a promising candidate for many applications particularly for the transportation in order to decarbonize this sector. Of the barriers, cost and durability represent two of the most significant challenges to achieving clean, reliable and cost-effective fuel cell systems. Proper management of the liquid water and heat produced in PEM fuel cells remains crucial to increase both its performance and durability. Indeed, large liquid water and temperature variations in the cell may accelerate long-term structural problems until irreversible degradation such as membrane micro-cracks (see ref.).

A two-phase flow model of a large surface PEM fuel cell is developed with the commercial COMSOL Multiphysics® software using the Finite Element Method (FEM). The model considers the cell as a multilayered system where each layer is accurately in-plane discretized to allow the simulation of local thermodynamics heterogeneities with a reasonable computing time. The numerical results are compared to experimental liquid water measurement obtained from neutron imaging tests in several operating conditions. According to the good agreement, the model is used to predict the distributions of current density, species concentrations, water content, etc. in all the components of the cell, while taking into account the real flow-field designs. Figure 1 shows the liquid water thickness (a) and the saturation (b) for a dedicated 3 cells stack experimentally tested for a high power automotive (Table 1). It appears that the liquid water accumulates at the anode Gas Diffusion Electrode (GDE) on the edges (dark red zone in Figure 1), inducing higher local current density and higher liquid water saturation in the external cathode channels, due to no-proper water convection by hydrogen gas (no anode channel in front of these zones).

Table 1. Operating conditions for a high power automotive application.

Experimental parameters		Setpoint
Inlet pressure reactant gases /bar		2.5
Coolant outlet temperature /°C		80.4
Coolant inlet temperature /°C		75.6
Current density /A cm^{-2}		1.1
Stoichiometry coefficient	Hydrogen	2
	Air	1.6
Relative humidity (%)	Hydrogen	49.7
	Air	59.5

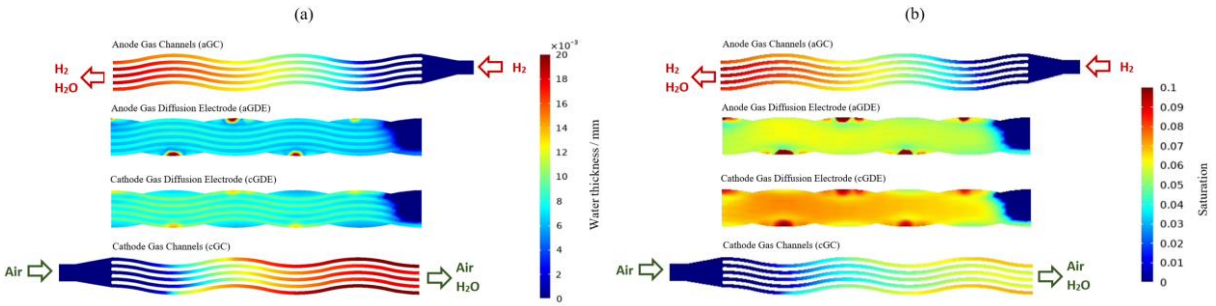


Figure 1. (a) Water thickness and (b) saturation distribution in the anode and cathode gas channels and gas diffusion electrode in the Setpoint No. 1 operating conditions.

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