A Computational Study of Stoichiometry Sensitivity of a PEM Fuel Cell with Multi-Parallel Flow Channels

M. A. Rahman [1], J.M. Mora[2], P. A. Chuang[1]

1. Thermal and Electrochemical Energy Laboratory (TEEL), Department of Mechanical Engineering, University of California, Merced, CA, USA

2. University of Philippines – Diliman, Quezon City, Philippines

Introduction

Even though parallel channel flow fields are efficient in uniform reactant distribution, they are also susceptible to liquid water accumulation and blockage due to low pressure drop. In this study, the effects of stoichiometry on water accumulation and fuel cell performance is analyzed in a fuel cell with 17 straight-parallel channels based on Comsol simulated results.

Operating Condition	
Temperature	40°C
Pressure	150 kPa
Relative Humidity	50%

Table 1. Operating conditions studied in COMSOL

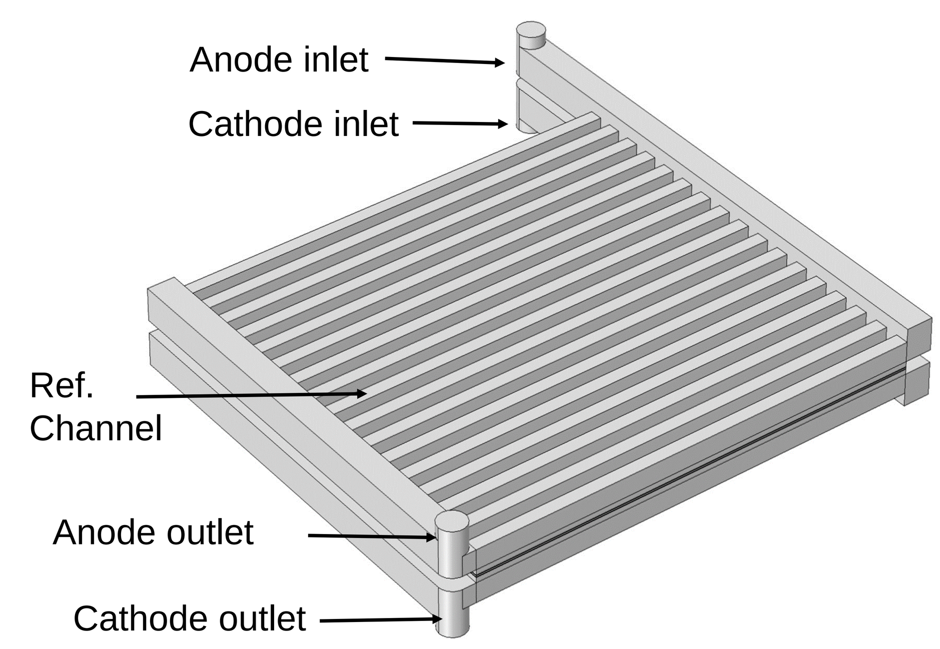

Figure 1. Simulated flow field geometry

Computational Methods

The fuel cell computational domains include inlet/exit manifolds, flow channels, diffusion layers, electrodes, and membrane. “Reacting flow in porous media” interface is used to solve both the Brinkman equation for momentum transport and Maxwell-Stefan equation for species diffusion. To solve for electrode kinetics, “Secondary current Distribution” interface is used, which solves Ohm’s law to obtain the electric potential. More equations and variables of our simulation method can be found in Table 2.

Physics	Equation	Variable
Electrochemistry	Ohm's Law	∅_l Electrolyte potential and ∅_s electric potential
	Charge Conservation	∅_l Electrolyte potential and ∅_s electric potential
	Linearized Butler-Volmer	HOR Overpotential
	Cathodic Tafel	ORR Overpotential
Fluid flow in porous media	Continuity	Velocity components of flow (u)
	Brinkman Equation	Velocity (u) and Pressure (P)
Mass Transport	Maxwell-Stefan Diffusion	Mass fraction (x)

Table 2. Physics, equations, and solved variables used in our simulation model

Mesh

User controlled structured mesh has been created on YZ plane in the channel, which is then swept in X direction. In the inlet and outlet manifold, physics controlled tetrahedral mesh has been used. Figure 2 shows the generated mesh for simulation.

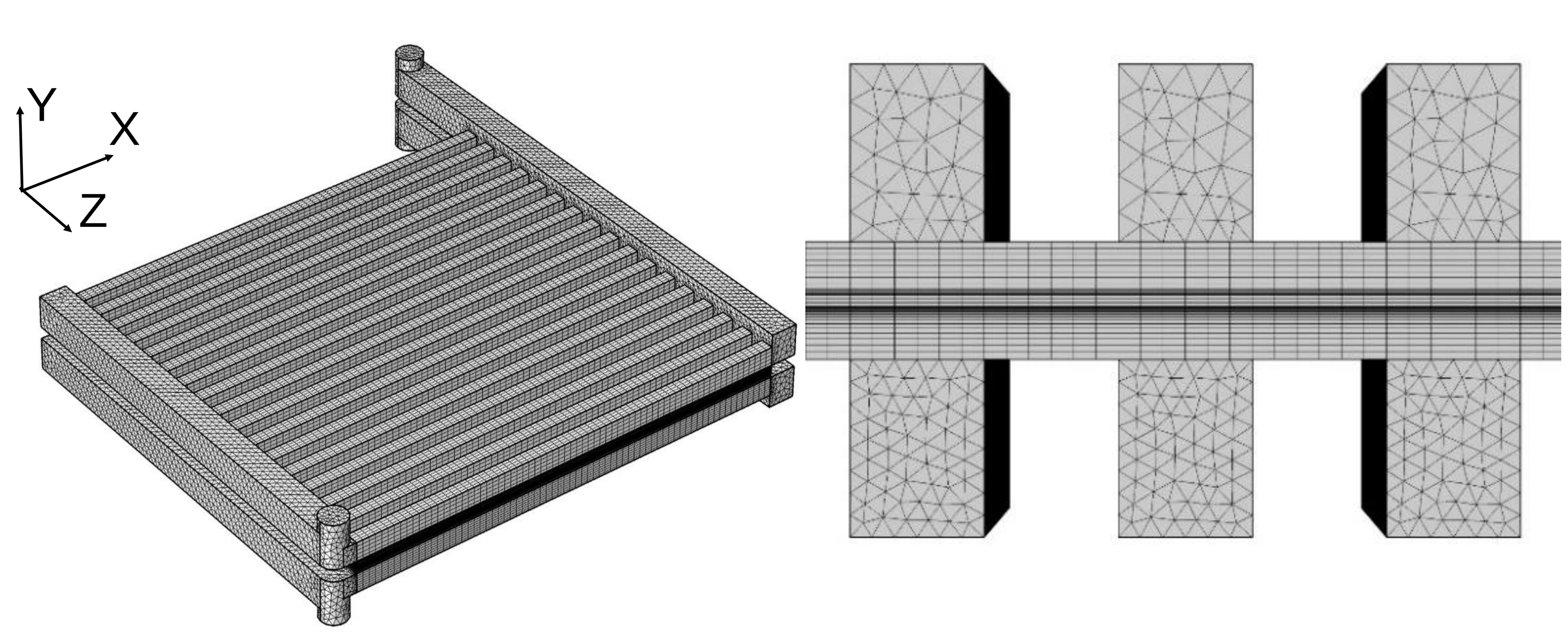

Figure 2. User controlled mapped mesh in diffusion layers, electrodes, and membrane

Results

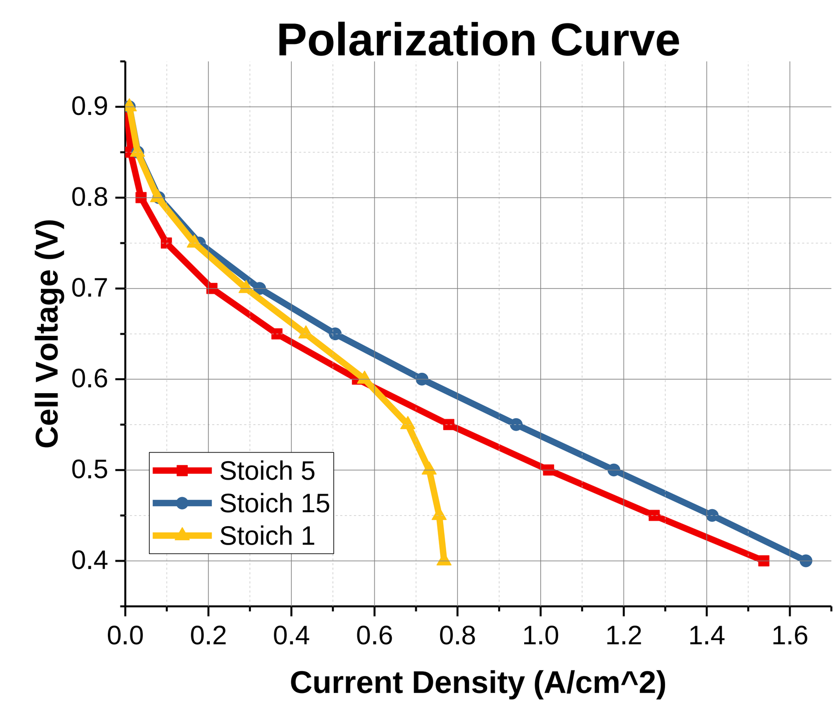

Figure 3. Polarization curve

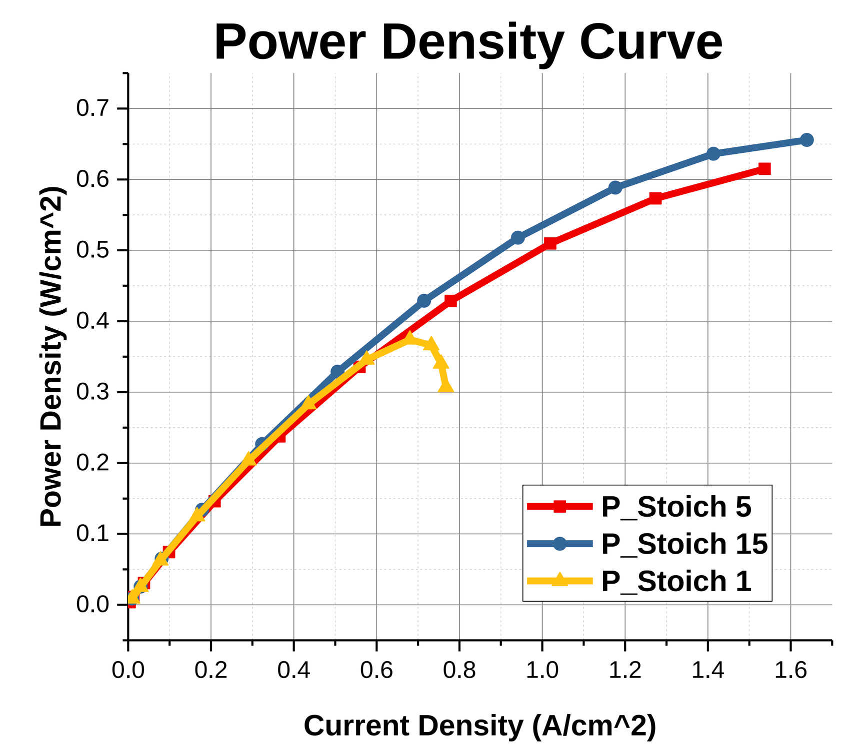

Figure 4. Power density curve

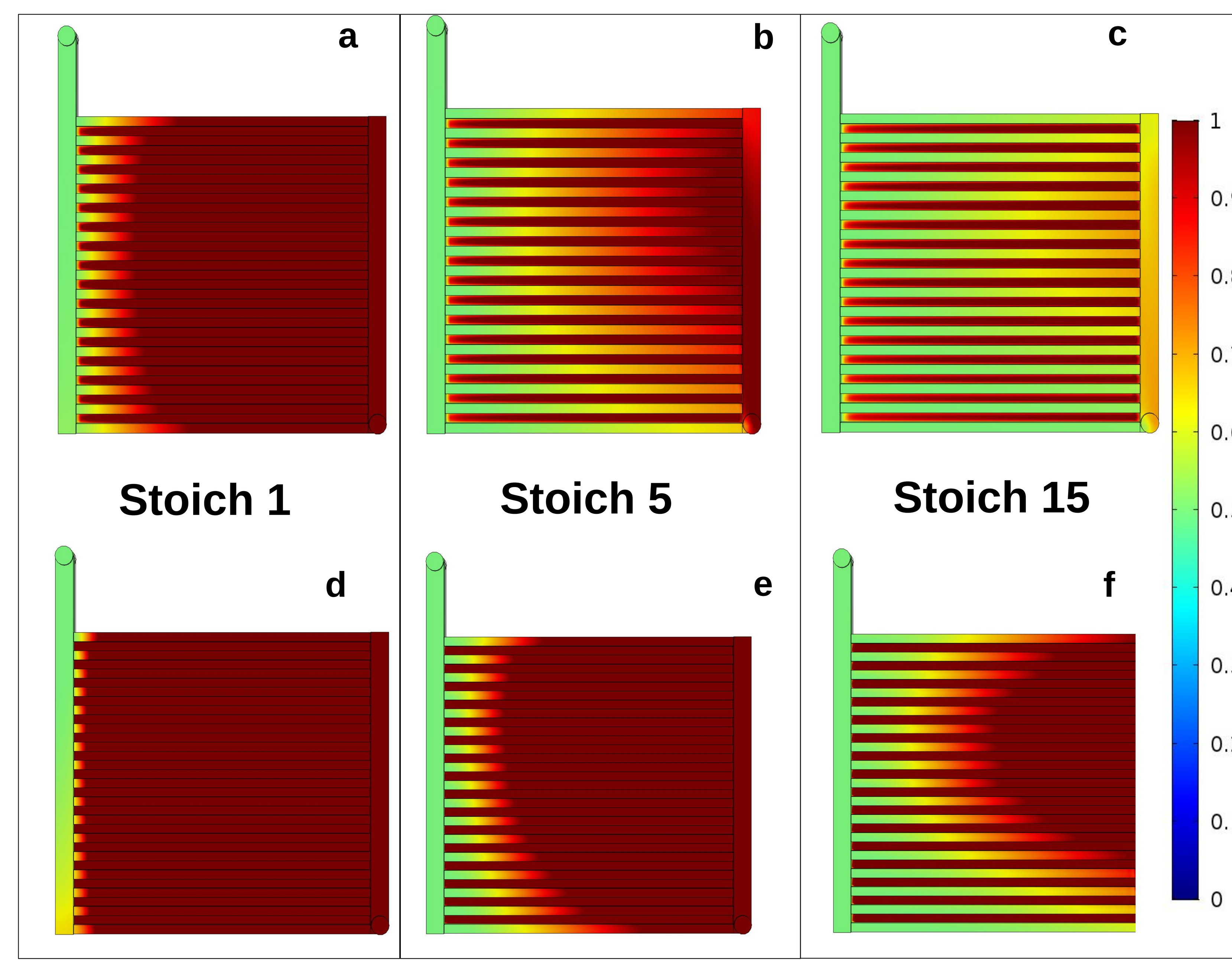

Figure 5. The distribution of relative humidity in cathode channels when the cell is operated at 0.7 V (a,b,c) and 0.4 V (d,e,f)

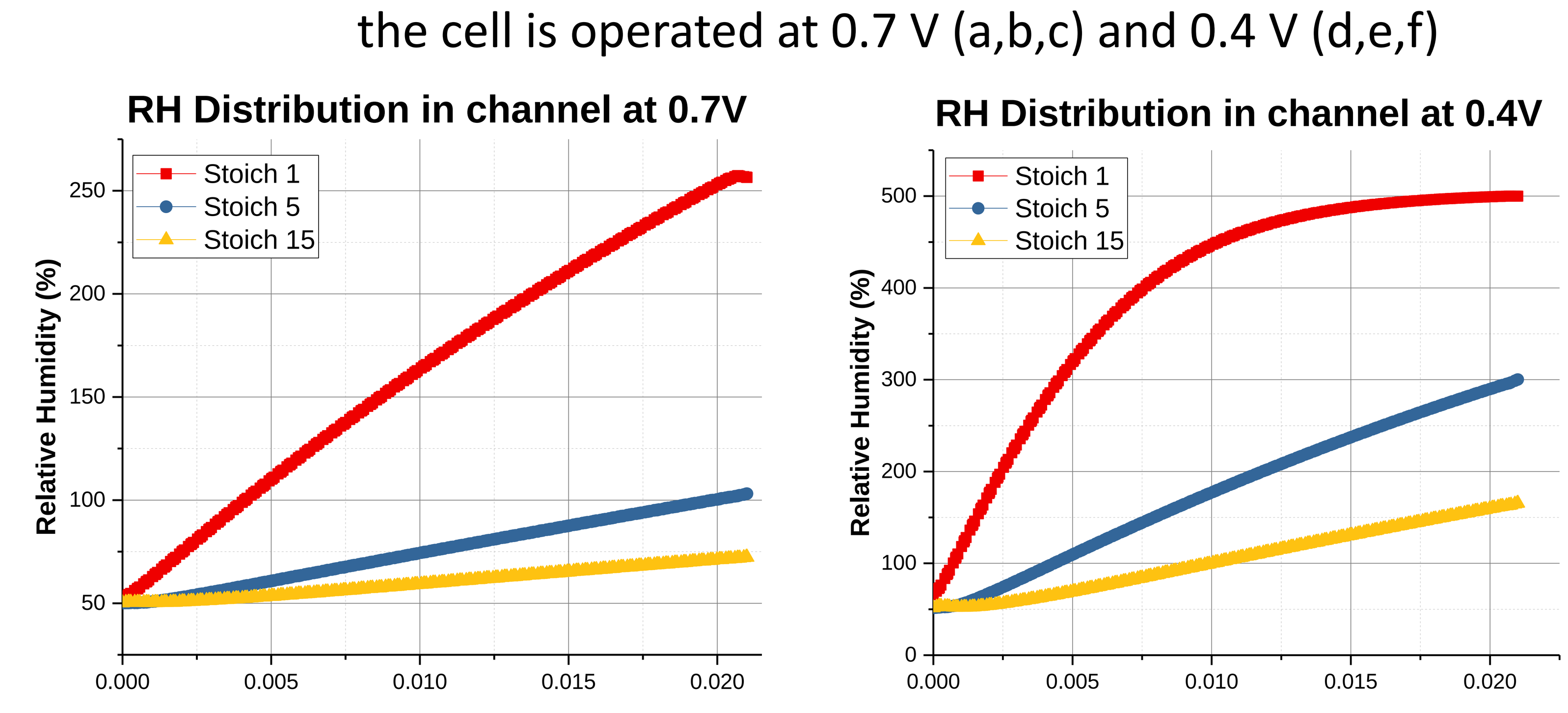

Figure 6. Distribution of relative humidity along the channel when the cell is operated at 0.7 V (left) and 0.4 V (right)

Conclusions

A three dimensional isothermal steady-state simulation model was performed using COMSOL Multiphysics 5.2. Our results demonstrate that with the increase of stoichiometric flow rate, water accumulation in channel was reduced significantly. At an operating voltage of 0.7V, the level of saturated liquid water (RH > 100%) in the reference channel (shown in Fig. 1) is reduced to 0% at the channel exit when the stoichiometric flow rate is greater than 5.

References:

1. E.U. Ubong et al. Three-Dimensional Modeling and Experimental Study of a High Temperature PBI-Based PEM Fuel Cell, Journal of The Electrochemical Society, **156** B1276-B1282 (2009)

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