Numerical Results of Two 3D Coupled Models of a Unitary PEM Fuel Cell of 144cm²

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Abstract

This computational implementation presents a new strategy of coupling two 3D models to satisfy the requirements of the comprehensive model of a unitary Proton Exchange Membrane - PEM fuel cell, including its internal geometries and constitutive materials, as well as distinct physical and chemical processes. Those different simultaneous processes required computational effort and the solution was the coupling of two complementary models to the overall modeling of fuel cell. The models are called Entire Plate Model and MEA Model (MEA - Membrane Electrodes Assembly). The problem is to get pressure values from the first model (gas distribution channels and porous layer) and then use those answers as initial values to simulate the second model (electrodes and membrane). Data analyses have proved that from ten thousand elements of mesh there was no mesh refinement dependence for MEA Model. Entire Plate Model uses five reference channels (Figure 1) which are represented by the first channel of each set of 12 channels, a total of 60 channels were designed for proposed experiments. These reference channels allow sampling of pressure and velocity for Entire Plate. These readings mean the integral over boundary domains and were tabulated as initial values in MEA Model. The MEA Model (Figure 2) consists of a 1.0 x 1.0 x 0.6 mm³ 3D geometry that simulates the average experimental conditions of the cell from pressure values given by the first model. The electrochemical reactions and the mass conservation were defined in MEA Model, as well as the idea of agglomerate in the catalytic layer and charge transport in electrolyte membrane. Numerical results of anode and cathode mass fractions, current density, pressure, velocity and convergence graphics were generated with COMSOL Multiphyscs® software. The polarization planes generated from MEA Model are showed in Figure 3, presenting the potential dependence of current density at cathode collector. Concerning to the experimental part, a prototype of a unitary fuel cell of 144cm² of geometric area was operated at laboratory with the purpose of validating the numerical computer model proposed. Polarization curves are showed in Figure 4, presenting numerical versus experimental results. The final model is robust and useful as a tool for design and optimization of PEM fuel cells in a wide range of operating conditions.

Reference

[1] M. Linardi, Introdução à Ciência e Tecnologia de Células a Combustível, São Paulo, Artliber, 2010.

[2] J. Zhang, PEM Fuel Cell Electrocatalysts and Catalyst Layers: Fundamentals and Applications, Springer-Verlag London Limited, 2008.

[3] T.E. Springer; I.D. Raistrick, J. Eletrochem. Soc. 136 (1989) 1594-1603.

[4] K. Broka, Characterization of the Components of the Proton Exchange Membrane Fuel Cell, Techn. Lic. Thesis, Royal Institute of Technology, Stockholm, 1995.

Figures used in the abstract

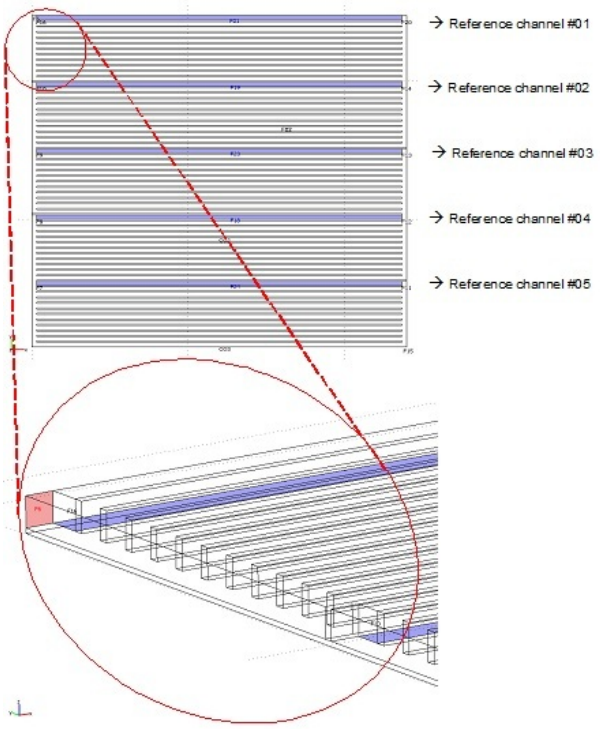

Figure 1: Reference channels #01 to #05 for the Entire Plate Model 3D geometry.

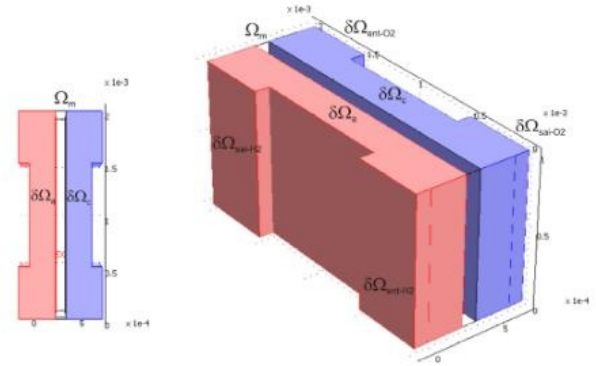

Figure 2: MEA Model 3D geometry.

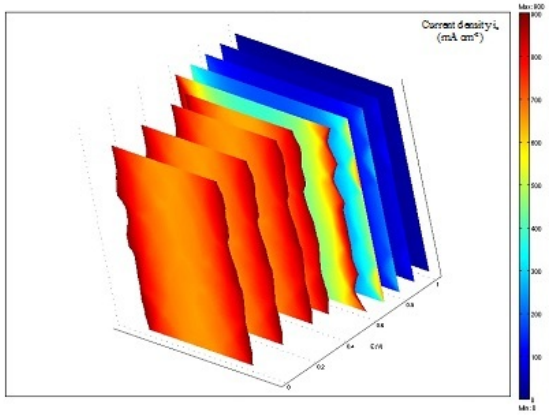

Figure 3: Polarization planes: current density x potential, MEA Model, T = 348K, pref = 1 atm, pH2 = pO2 = 52.45 Pa, 0 < E(V) < 1.0.

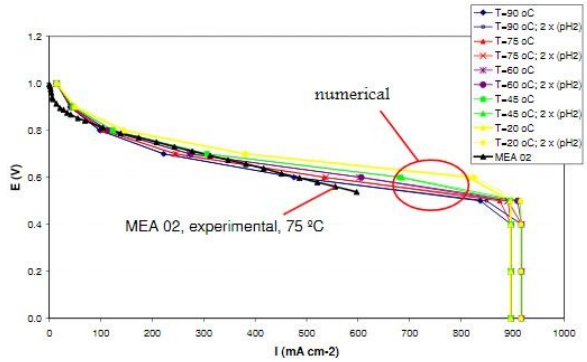

Figure 4: Polarization curves: numerical versus experimental results.