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APPLICATION OF CFD TECHNIQUES IN THE MODELLING AND SIMULATION OF PEM FUEL CELL´S FLOW CHANNELS

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ABSTRACT

The Computational Fluid Dynamic (CFD) is a very useful tool to explore the connection between the transport of reactants and products within the fuel cell, and overall cell performance through mass transport optimization. CFD simulates hydrogen and oxygen gases flows in a fuel cell to reduce the production cost of bipolar plates. In this work, two configurations of gas flow channels were studied by simulation with COMSOL software and a preliminary experimental test was performed to validate the simulated model.

INTRODUCTION

The Proton Exchange Membrane Fuel Cell (PEMFC) is an electrochemical device which converts chemical energy into electric energy and consists of two main parts. The first one is the Membrane Electrode Assembly (MEA): an electrolyte between two Gas Diffusion Electrodes (GDE), the anode and the cathode. The second one is the gas flow field plates, called bipolar plates. The bipolar plates [1] have many functions in a fuel cell such as distribute reactant gases (hydrogen and air or oxygen) uniformly, collect and conduct electrical current, and remove heat and water from the electrodes. The bipolar plates make the cell robust and rigid to support the mechanical impacts of portable and automotive applications. The cost of the bipolar plates corresponds up to 37% of the total stack costs and approximately 80% of the total weight of the stack [2,3], depending on the manufacture technology.

The search for reliable computational models for PEMFC studies is a challenge because it involves several transport phenomena: mass, momentum and energy balances with electrochemical reactions, transport of water through the membrane and transport of electrons through solid matrix. By using CFD techniques it is possible to simulate different flow channels configurations to optimize the gas reactants distribution along the electrode surface and as a consequence to improve the mass transport. Reliable simulations are important in order to reduce the number of bipolar plates configurations and fuel cell tests, and consequently, the total cost of the project [4,5].

In this work, two flow channels configurations were studied by simulation with COMSOL software and preliminary experimental tests were performed to validate the applied model.

EXPERIMENTAL

Two single cells, both with MEAs of 144 cm² active area and Pt loading of 0.4 mg cm^{-2}, were manufactured. The serpentine flow field configurations for the bipolar plates were chosen. The dimensions of the bipolar plate channels are summarized in Table 1.

Table 1: Dimensions of the bipolar plate channels.

Prototype	Width [mm]	Depth [mm]	Ribs [mm]
A	2	2	2
B	1.5	1.5	0.5

A mesh study was performed by using the 2D and 3D models to determine the minimum number of elements required to solve accurately the equations over the solution domain. Simulations of diffusion process in porous media,

electrochemical reactions, and conduction/convection process were studied. Once all of the global iterations have been completed, the simulations results were compared with experimental data.

RESULTS AND DISCUSSION

Simulations of pressure, velocity and gas diffusion profiles for both prototypes were made in a 3D geometry. However, in this work, only the velocity in z-axis is presented. This velocity can represent how much gas reaches the catalytic layer. In Fig. 1 the z-velocities profiles for the cross-section view of two flow square channels of the prototypes are showed. In prototype B, because of the small rib, the dead zone, which is the area where the gas phase has no contact with the catalytic layer, is smaller than the one of prototype A. This small dead zone indicates that there is a large contact area of reactant gas with the electrode surface, improving the gas distribution and maximizing the three-phase boundary in the catalytic layer.

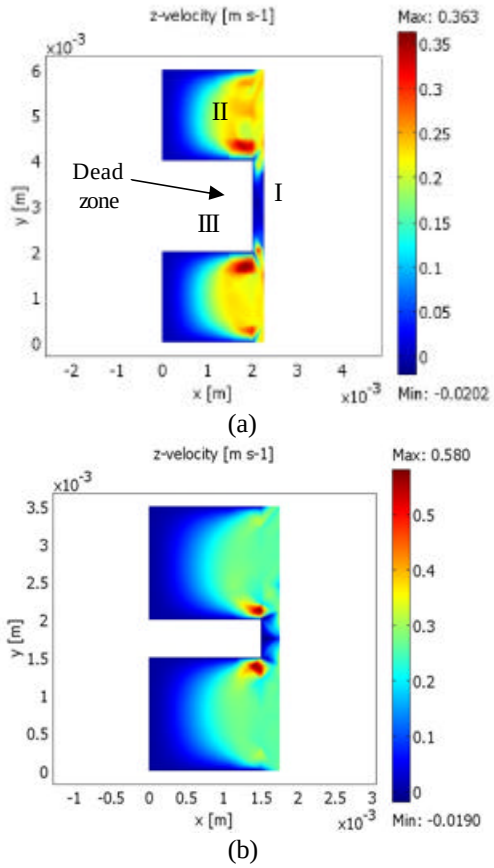

Fig. 1: z-velocity slice of (a) prototype A and (b) prototype B The numbers I, II and III represent the position of the catalytic layer, channel and rib, respectively.

The prototypes were fabricated and tested at IPEN laboratories and they were characterized by polarization curves as shown in Fig. 2. The polarization curves evidenced that the prototype B has significantly better performance than the prototype A. The current density values at 0.6V were 166.7 mA cm^{-2} and 470.6 mA cm^{-2} for prototypes A and B, respectively. The experimental data corroborate the obtained results by numerical methods.

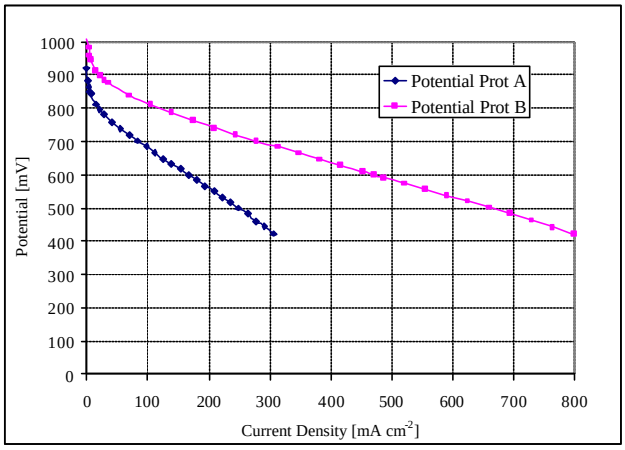

Fig. 2: Polarization curves of prototype A and B.

Another reason for the best results in prototype B was the 50 % larger channel area in contact with gas diffusion electrode, which provides higher active area available for the electrochemical reaction. Additionally, the higher gas velocities in flow fields of prototype B decreased the gas stagnation points along the channels.

CONCLUSIONS

The CFD techniques are a very helpful tool to simulate the behavior of the gases in flow channels of PEMFC bipolar plates. The flow channels simulations results showed better performance in prototype B than the prototype A. These results were corroborated by experimental data.

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