Study of Flow Field Design for Improving PEMFC Performance

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Introduction

PEMFC stacks are construction of single cells typically joined with bi-polar plates. Usually, the stack performance (total voltage/number of cells in the stack) is less than a single cell at the same current density. The performance of a stack not only depends on the conductivity of the plates but also on the flow field design for maintaining uniform humidity and hydration of the MEA in each cell. The objective of the study is to understand the physics in the flow field and show the effects of the flow field geometry changes on the cell performance.

In this work, numerical model of PEMFC will be developed for a 25-cm^2 single cell and will be scaled up to 200-cm^2 reacting areas for various flow field patterns. The numerical results will predict the distribution of local current density, water (liquid and vapor), temperature, and pressure. These results will be compared with the experimental data. The numerical results will show the effect of scale-up and flow pattern design on PEM fuel cell performance. The model will also show the changes in the local flux of water due to the electro-osmotic controlled or back diffusion controlled for different flow field designs and operating conditions.

Numerical

Computational Fluid Dynamics (CFD) is gaining more interest as a tool to understand fuel cell performance. The model calculations provide insight into the fuel cell on a local level and describe distributions of current, heat, and water. Therefore, modeling will help to understand the mechanisms inside the fuel cell and identify limiting parameters. Shimpalee and Dutta.[1] and Lee *et al.*[2] have detailed a three-dimensional, two-phase, non-isothermal model of PEMFC's. This model has been validated with water balances and polarization curves. The model considers mass, momentum, and heat transfer, proton migration and water transport in the ionomeric membrane, and electrochemical reactions in the electrodes. The model will be exercised using both single and parallel algorithms for a range of stoichiometric ratios and inlet humidity conditions. The geometries on large scale are easily decomposed into segments for parallel computing technique. These results will be compared and analyzed with our experimental data.

Experimental

Experiments focus on the performance of PEM fuel cells for the various flow field designs. In the experiment, four different flow field patterns (active area: 25 cm^2) were examined: two single serpentine flow fields (Type 1A and 1B) and two five-fold serpentine flow fields (Type 5A and 5B). At the beginning, the pressure drop between inlet and outlet was measured. Figure 1 shows the pressure drops for various flow patterns. The flow pattern Type 1B shows the highest-pressure drop. Also, there is no pressure drop difference observed between Type 5A and 5B. After measuring the pressure drop, the cell performance tests were conducted for the various flow fields. They are shown in Figure 2. The highest performance was observed with flow field Type 1B. Also, the results show that the cell performance of Type 5A is higher than that of Type 5B. Note that the pressure drop of Type 5A and 5B are comparable. All of the data reported here were obtained with PRIMEA® Series 5510 MEA (W.L. Gore) and catalyst loadings of 0.4 mg/cm^2 Pt on both anode and cathode. Cell temperature and back pressure were 70°C and 101 kPa, respectively. Similar experiments will be conducted for a 200-cm^2 cell for showing scale up effects with various flow patterns.

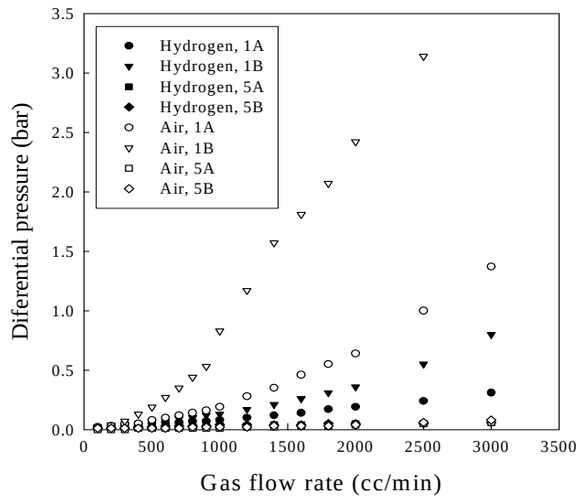

Fig. 1. Pressure drop on anode and cathode side for various flow fields.

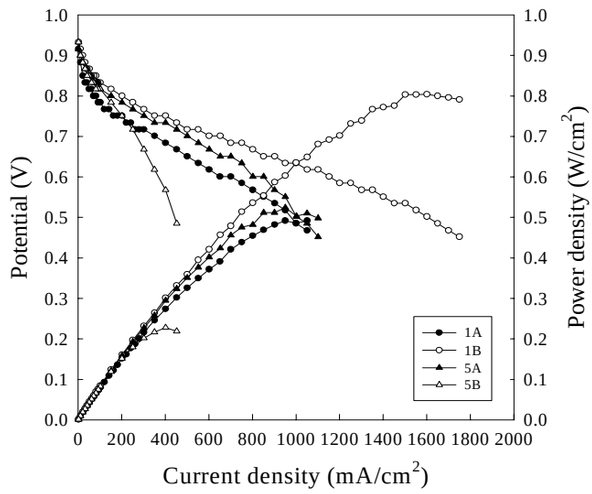

Fig. 2. Polarization and power curve for various flow fields at 70°C

References

1. S. Shimpalee and S. Dutta, *Numerical Heat Transfer-Part* A, 38, 111-128, 2000.
2. W-k. Lee, S. Shimpalee, and J.W. Van Zee, *J. Electrochem. Soc.*, 150 (3), A341, 2003.