Residual Water Distribution and Removal from Polymer Electrolyte Fuel Cells

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Service Provided: Neutron Beam Laboratory

Sponsors: Automotive manufacturer

Introduction

Polymer electrolyte fuel cells (PEFCs) are a promising energy source due to their high efficiency and low emissions. However, there are still many components and processes associated with PEFCs that need to be optimized. One major concern with PEFCs is the water distribution in the components. Water is required to conduct ions in the membrane but too much water can cover part or all of the catalyst layer, decrease reactant availability, and cause performance loss. Another concern with PEFCs is that in cold temperatures there can be degradation due to water freezing and expanding in the membrane, catalyst layers, diffusion media (DM), or the interfaces between these components. Therefore, the cell must be built to withstand this degradation and as much water as possible must be removed, or purged, before shutdown.

Unfortunately, non-intrusive water visualization within a fuel cell is difficult to achieve. Neutron radiography uses a neutron beam that is attenuated significantly by the water in the fuel cell and shows an image of the water distribution. It produces excellent resolution and remains non-intrusive. This is helpful in performance tests and model validation efforts.

Experimental Setup

The tests in this study were done in the Neutron Beam Lab at the Penn State Radiation Science and Engineering Center and the Breazeale Nuclear Reactor provided the thermal neutron beam. The water in the fuel cell attenuates the neutron beam and a CCD camera is used to capture both steady state images and transient videos. Custom software developed by PSU quantifies the liquid water in the cell and produces water mass versus cell location images. The water in the channels and in the DM under the channels is also differentiated from the water under the landings of the flow field using a masking technique.

The fuel cell in this study, seen in Figure 1, has a parallel design with seven channels and the anode and cathode flows were setup in a counter flow arrangement.

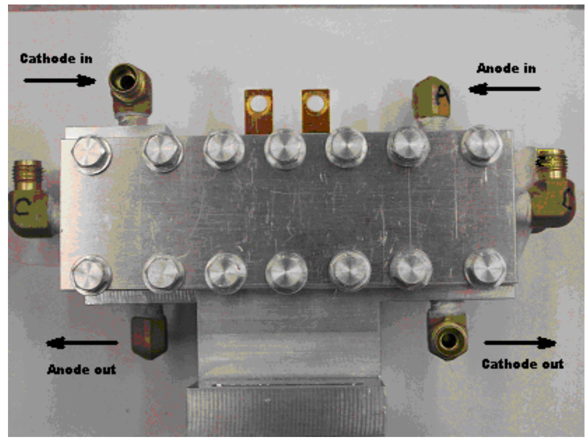

FIGURE 1: Fuel cell used in this study

The tests in this study were conducted at four different current densities, two flow rates, two humidity conditions, and with two different diffusion media (DM) materials. Carbon fiber paper, with a thickness of 180 μm, and carbon fiber cloth, with a thickness of 250 μm, were the two DM materials used. The cell was kept at constant temperature (80 °C) and pressure (100 kPa) for all tests.

Results

The low flow rate in the test was 174 sccm at the anode and 417 sccm at the cathode. The higher flow rate was 2.5 times the low flow rate. In all the pairs of tests comparing flow rate only, the water mass in the cell decreased significantly. Figure 2 shows false-color radiographs of two such tests. The high flow rate test (Figure 2b) contains 27.2% less water than the low flow rate test (Figure 2a). The water mass decrease in the channel region was 30.7% and in the landing region it was 24.0%. The water mass decreased more in the channel region in all similar cases because the water could be convectively removed from the channels, while the water under the landings had to diffuse out to the channels and then be removed. These results also suggest that the water in the channel is in a droplet form and not in a film on the wall because a droplet has a higher frontal area and will be convectively removed more easily.

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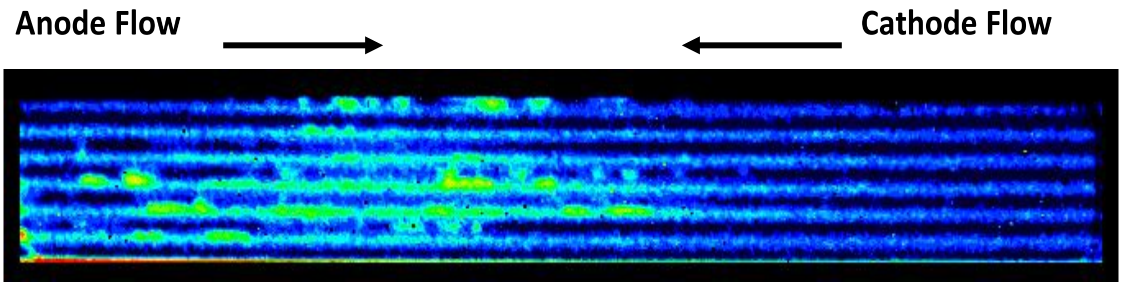
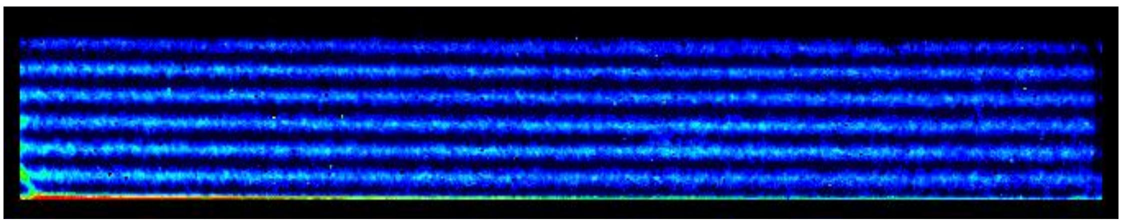


a) Cloth DM, i=0.35 A/cm^2, V=0.761 V, A/C=174/417 sccm, RH A/C= 90/80 °C

Calculated Water Mass (Total/Channel/Land)=145.8/71.7/74.1 mg



b) Cloth DM, i=0.35 A/cm^2, V=0.749 V, A/C=436/1044 sccm, RH A/C= 90/80 °C

Calculated Water Mass (Total/Channel/Land)=106.1/49.7/56.3 mg

FIGURE 2. Neutron Radiography Images at low flow rate (a) and high flow rate (b)

When comparing the two DM materials, it was found that the water in the paper DM tends to be under the lands more than the cloth DM. Both DM's have approximately the same total water mass in the cell. In Figure 3, the average water mass values of all ten tests conducted were normalized to account for the different thickness values of the DMs and the different areas of the three regions (total, channel and landing regions). The paper DM is shown to have much more water mass under the lands than the cloth DM, again averaging the water mass values of all ten tests. The cloth DM only has slightly more water in the landing region than in the channel region.

Conclusions

Neutron radiography is an excellent non-intrusive technique to visualize the water distribution in a PEFC. The results of this study show that an increased flow rate can remove water from the cell, especially the channels and in the DM under the channels. Also, the cloth DM contained less water under the lands compared to the paper DM. This would make the cloth DM easier to purge since the water under the landings is more difficult to remove. These results have a deep impact on the design of automotive fuel cells to reduce the residual liquid water fraction in the porous media, which will help improve low temperature performance.

Publications

1. A. Turhan, K. Heller, J. S. Brenizer, K. Ünlü, M. M. Mench, "Influence of operating parameters on liquid water distribution and flooding in a PEFC," Abstract 942 Presented at the 208th Electrochemical Society Meeting, Los Angeles, California, 17-19 October 2005.
2. Mench, M. M., "Advanced Diagnostics for PEFCs," *(Invited) Gordon Research Conference on Fuel Cells*, Bristol, RI., July 2004.

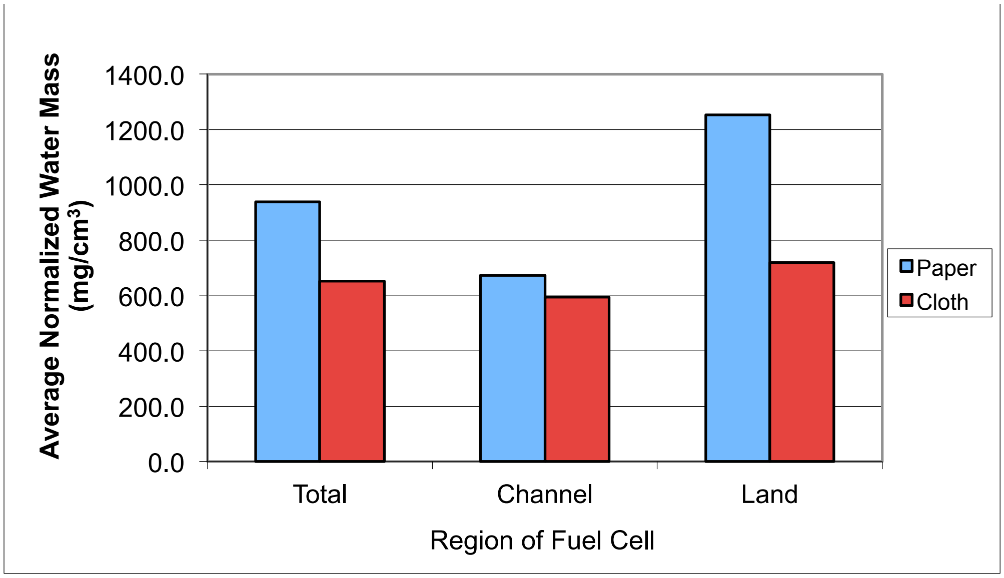


FIGURE 3. Water Mass Values Per Unit Volume of DM