Experimental report

09/12/2016

Proposal: **9-11-1708** **Council:** 4/2014

Title: Water distribution in a full-scaleProton Exchange Membrane Fuel Cell: Effect of the gas flow field design and of the fuel composition

Research area: Engineering

This proposal is a continuation of 9-11-1537

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Samples: Perfluorosulfonated ionomer

Instrument	Requested days	Allocated days	From	To
D33	0	0		
D22	4	2	03/06/2016	06/06/2016

Abstract:

With its fast starting at room temperature, its versatility, its high power density and efficiency, the Proton exchange membrane fuel cell (PEMFC) is considered a promising energy source as an alternative to fossil fuels, for use in portable, stationary and transport applications.
One of the main issues affecting its power output, stability, and longevity is the quantity and distribution of water in the system.

This proposal aims to have access, for the first time, to crucial information on the water management of full-scale PEMFC (around 200 cm²) which are required for the improvement of real systems.

We propose to determine the effect onto the water repartition of the :
- operating conditions of transportation and stationary applications.
- gas flow field design
- amount of impurities (CO) in the hydrogen produced by reforming of natural gas and used in stationary applications

A high neutron flux with a small beam is required to obtain the necessary time and spatial resolutions. Hence, these SANS experiments can be only conducted at ILL.

Experimental report

Experiment description:

The main goal of the experiment was to measure water distribution on an operating proton exchange membrane fuel cell with the last generation of design (10x16 cm), in order to understand how water is managed in this novel type of cell.

For this experiment, we probed the fuel cell with a beam of 13 mm diameter, at 5 different positions on the active area (Figure 1). Besides from having a new design, the membrane electrode assembly

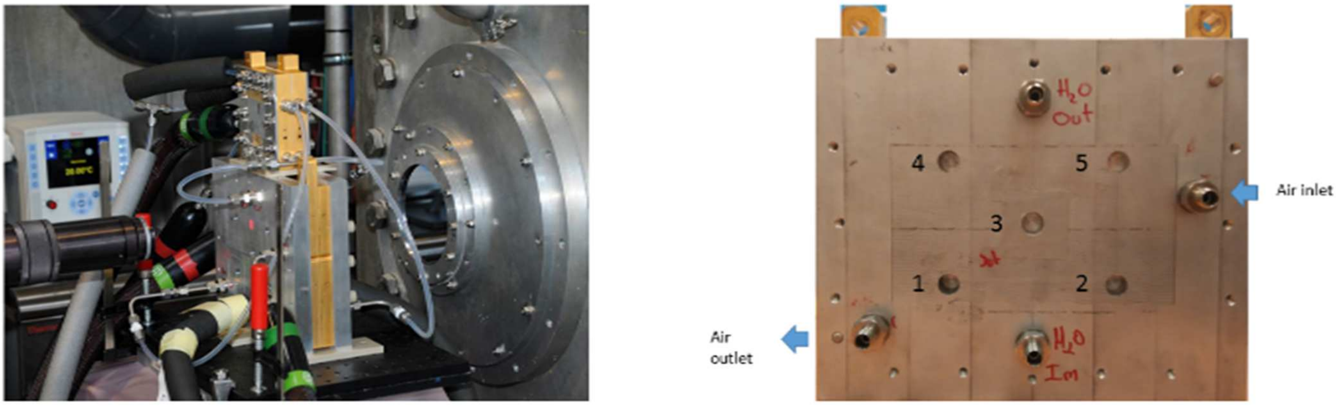

Figure 1: Experimental setup for the reference measurements, with the small surface cell on top of the (left), and a picture of the cell with the positions annotated (right).

(MEA) was composed of state of the art membrane, around 20 µm in thickness. Since it has not been studied previously, we had to measure the swelling properties of this membrane. This was also the occasion for us to check whether a free membrane has the same swelling behavior than when integrated in a MEA where it is constrained, or not. We thus also prepared another cell in which the membrane is free to swell in order to perform such study. After characterizing the swelling behavior, we operated the fuel cell and measured the water content at 4 different current conditions, in order to see how the water was managed under operating conditions. When we first started drawing current, we encountered technical problems with the fuel cell, as it was performing very poorly. After troubleshooting, we found out that we were having issues with the current aluminum collecting plates, so we replaced them with a stainless steel version and got better performances.

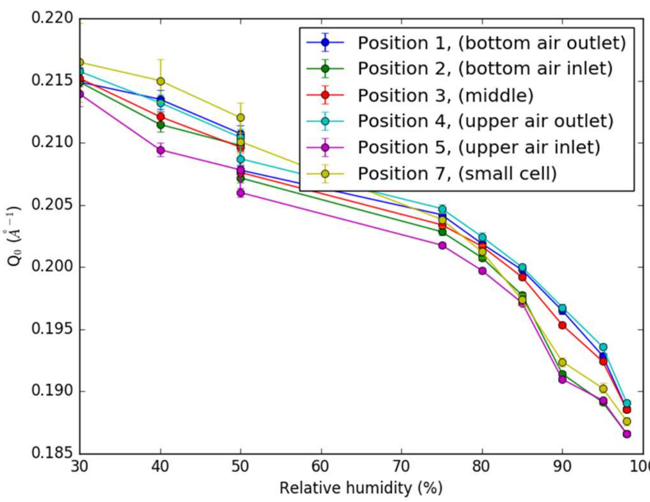

Figure 2: Ionomer peak position as a function of relative humidity, for the different positions,at 25C.

Preliminary results:

Swelling behavior of Gore membranes:

The swelling behavior of ionomer membranes is commonly monitored by following the position of the ionomer peak as a function of hydration, which is achieved by equilibrating the membrane at a desired relative humidity. This is the first that this study has been conducted on this state-of-the-art membrane. The spectra are fitted with a sum of a Gaussian, a decaying exponential (accounting for not perfect subtraction of the polymer component) and a Q-constant background (accounting for the incoherent background).

Figure 2 shows the position on this peak as a function of relative humidity. We can see that there are slight differences between positions 1, 3, 4 and 2, 5. This is most certainly caused by the geometry of the cell: positions 2 and 5 are near the air inlet, while positions 1 and 4 near the air outler. Another interesting finding is that the swelling behavior at position 7 (membrane alone in a 25cm^2 cell), which contains no GDL and thus has an unconstrained membrane, is comparable to positions 5 and 2. **This allows us to conclude that the constraining of a membrane in a fuel cell context has no effect on its swelling properties**. What dominates is the position in the cell, which is linked to the gas flow configuration.

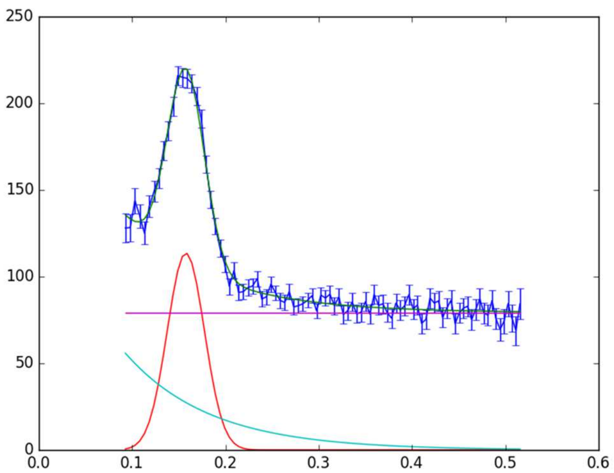

Figure 3: Example of a fit on the cell with steel current collecting plates

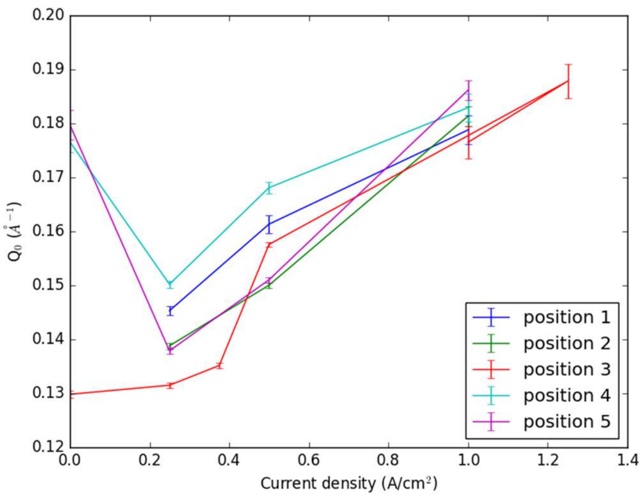

Figure 4: Ionomer peak position as a function of the current density for the cell with the steel current collecting plates, for decreasing current densities.

Measurements on an operating fuel cell:

Stainless steel has a very high scattering cross section, leading to a huge signal arising from the current collecting plates. Nevertheless, after proper subtraction, it was possible to extract the ionomer peak position quite accurately, although the background signal being so huge. An example of a fit is showed in figure 3. We recorded data at various current densities (OCV, 0.2, 0.4, 0.5, 1.0 and 1.2 A/cm^2). The results of the fit are presented in figure 4. **Globally, the membrane dries when the current density increases, and then swells when the current density is 0.2 A/cm^2, which is the opposite behavior of what we have already measured on a small surface (5 cm*5 cm). Also, it is interesting to note that positions 2 and 5 (air inlet) share a similar trends. The same is observed for positions 1 and 4 (air outlet).**