Convection Considerations in PEMFC Flow Field Design

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The proton exchange membrane fuel cell (PEMFC) is comprised of a proton-conductive membrane that is in contact with a cathode catalyst layer on one side and an anode catalyst layer on the other side, sandwiched between two gas diffusion layers (GDL). Gas diffusion layers serve as current collectors that allow ready access of the fuel and oxidant to anode and cathode catalyst surfaces, respectively. The mass transport mechanism in a GDL is typically assumed to be bulk gas phase diffusion by assuming that gas permeability of gas diffusion layers is relatively small [1].

Limiting current of a cathode is an extrapolated current density at zero voltage where oxygen concentration at the cathode catalyst layer goes to zero. It is representative of the mass transport limitation on the cathode of a PEMFC. Experimental data has shown that different gas diffusion layers with different gas permeability yield different limiting currents. However, the limiting currents obtained from using O_2 balanced in He and O_2 balanced in N_2 have shown no significant difference. If bulk gas phase diffusion is the dominant mass transport mechanism, they should be significantly different because the binary diffusion coefficient of O_2 in He is four times that of O_2 in N_2 [2]. These experimental results suggest that in many cases other mechanisms besides bulk gas diffusion could be controlling oxygen transport, i.e. Knudsen diffusion, oxygen permeation through ionomer in the cathode catalyst layer, and convection through the GDL. Effects of convection through the GDL are the focus of this work.

Measurements were conducted to determine the pressure drop through channels of various flow fields with different designs. It is to be noted that interdigitated flow fields, which are designed to enhance convection between dead-ended inlet channels and exit channels through the GDL [3], are not in the scope of this work. Flow fields considered here are those with the transport mechanism through the GDL typically assumed to be predominantly diffusion. Each flow field yields different pressure drop at the same total gas flow rate, as shown in Figure 1. Pressure drop through the channel of a 6.25-cm^2 single serpentine flow field with and without a GDL is shown in Figure 2. A significant difference in pressure drop results between these two cases show the significance of convection through the GDL. The pressure drop between two adjacent flow channels forces gas flow from the higher-pressure channel to the adjacent lower-pressure channel through the GDL. The oxygen-rich flow thus passes closer to the cathode catalyst. The significance of convection on oxygen transport depends on the driving force, which is the pressure drop between two adjacent flow channels in each flow field, and the permeability of the GDL. Higher overall pressure drop through channels of a flow field enhances convection in the gas diffusion layer, thereby helping the overall oxygen transport. However, the overall pressure drop through channels needs to be within a reasonable range for practical fuel cell system design.

A simple mathematical model has been developed using the permeability of a GDL as an input to quantitatively determine the forced convective flow through a GDL for single serpentine flow fields. The model was calibrated with experimental pressure drop data of flow though channels with and without a GDL to verify the validity of its prediction. Convective flow through a GDL and the overall pressure drop through a flow field, with convection effects included, can be determined by the model. Understanding of the interaction between GDL permeability and flow field geometry can thus be obtained. An optimized system, in terms of the flow field geometry and GDL permeability, with a maximized convective flow at a minimized overall pressure drop through the flow field can be obtained through an application of the model.

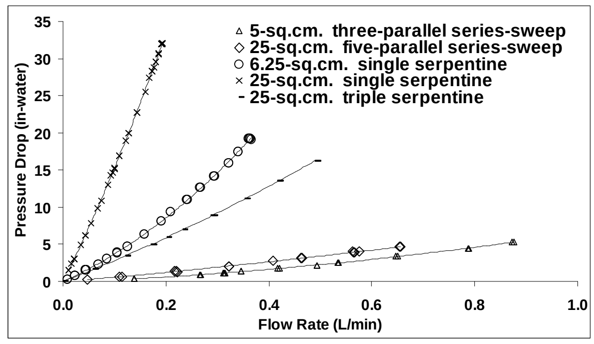

Fig.1 Pressure drop of flow through different flow fields

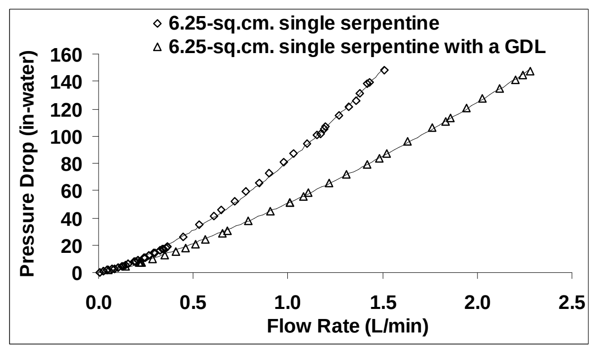

Fig. 2 Pressure drop of flow through a 6.25-cm^2 single serpentine flow field with and without a GDL

References

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