Flow Field Optimization for Proton Exchange Membrane Fuel Cells

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Abstract : The flow field design in the bipolar plates affects the performance of the proton exchange membrane (PEM) fuel cell. This work adopted a combined optimization procedure, including a simplified conjugate-gradient method and a completely three-dimensional, two-phase, non-isothermal fuel cell model, to look for optimal flow field design for a single serpentine fuel cell of size 9×9 mm with five channels. For the direct solution, the two-fluid method was adopted to incorporate the heat effects using energy equations for entire cells. The model assumes that the system is steady; the inlet reactants are ideal gases; the flow is laminar; and the porous layers such as the diffusion layer, catalyst layer and PEM are isotropic. The model includes continuity, momentum and species equations for gaseous species, liquid water transport equations in the channels, gas diffusion layers, and catalyst layers, water transport equation in the membrane, electron and proton transport equations. The Bulter-Volumer equation was used to describe electrochemical reactions in the catalyst layers. The cell output power density Pcell is maximized subjected to an optimal set of channel heights, H1-H5, and channel widths, W2-W5. The basic case with all channel heights and widths set at 1 mm yields a Pcell=7260 Wm-2. The optimal design displays a tapered characteristic for channels 1, 3 and 4, and a diverging characteristic in height for channels 2 and 5, producing a Pcell=8894 Wm-2, about 22.5% increment. The reduced channel heights of channels 2-4 significantly increase the sub-rib convection and widths for effectively removing liquid water and oxygen transport in gas diffusion layer. The final diverging channel minimizes the leakage of fuel to outlet via sub-rib convection from channel 4 to channel 5. Near-optimal design without huge loss in cell performance but is easily manufactured is tested. The use of a straight, final channel of 0.1 mm height has led to 7.37% power loss, while the design with all channel widths to be 1 mm with optimal channel heights obtained above yields only 1.68% loss of current density. The presence of a final, diverging channel has greater impact on cell performance than the fine adjustment of channel width at the simulation conditions set herein studied.

Keywords : optimization, flow field design, simplified conjugate-gradient method, serpentine flow field, sub-rib convection
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