A Comparative Study of the Basic Flow Field Designs for High Temperature Proton Exchange Membrane Fuel Cells

A. Lele[1], N. Lodha[1], R. Srivastava[1], A. Pandey[2], A. Paul[3]

[1]CSIR - National Chemical Laboratory, Pune, Maharashtra, India
[2]Reliance Industries Ltd., Reliance Technology Group, Navi Mumbai, Maharashtra, India
[3]CSIR - Central Electrochemical Research Institute, Karaikudi, Tamil Nadu, India

Abstract

A Proton Exchange Membrane Fuel Cell (PEMFC) comprises a membrane-electrode assembly sandwiched between two conducting 'monopolar' plates having engraved gas flow channels, also called the flow field. The purpose of the flow field is to provide sufficient residence time for the gases to undergo reactions at the two electrodes, effect a homogeneous distribution of reactant gases over the given reaction area, and facilitate reactant transport towards the catalyst layers where the reactions occur. While there can be a large number of design patterns for the flow field, almost all of them are based on some combinations of four basic types of flow field designs namely, pin, parallel, serpentine and interdigitated. Substantial literature studying changes in fuel cell performance due to arbitrary variations in flow field design exists, but precise design principles are still lacking. A comparative understanding of the four basic flow field designs and their effects on fuel cell performance can be the first step in this direction. In this work, we present an objective comparison between the four basic flow field types and their effect on the performance of a High Temperature Polymer Electrolyte Membrane Fuel Cell (HT-PEMFC).

The HT-PEMFC was modeled using the COMSOL Multiphysics® Batteries & Fuel Cells Module, which consists of symmetrical distribution of flow field, gas diffusion layer and catalyst layer about a central proton exchange membrane. The model parameters were selected based on earlier literature and further tweaked to fit the experimentally determined polarization curve and electrochemical impedance data for a HT-PEMFC. Simulations were run for all four flow field designs for varying oxidant flow rate and varying flow-channel volume for a given active area of 4 sq.cm.

Comparison between the four flow fields were achieved by plotting the current density at 0.6 V operating voltage versus the nominal mean residence time of the oxidant on the cathode. For conditions of varying oxidant flow rate, the current density for all flow fields except the interdigitated type showed saturation at low residence time. For conditions of varying flow-channel volume, all flow fields except the interdigitated type showed a non-monotonic behaviour with respect to residence time. While these predictions are in general agreement with experimental observations, for the first time, they show the effects of the basic flow field

designs when compared at identical conditions and also point to the underlying reasons for the observed differences. For instance, the interdigitated flow field showed dominant contribution of convective flux from flow channels to the catalyst layer, whereas for the other three flow fields, the dominant contribution was that of diffusive flux. Furthermore, the inherent properties of the flow fields can be compared by looking at the residence time distribution and pressure drop experienced by the oxidant. Interestingly, the inherent pressure drop in the flow field has a different effect than the back-pressure, which is generally used as an alternative to high gas flow rate.