Predicting Water and Current Distributions of a Commercial-Size PEMFC.

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Introduction

Proton Exchange Membrane Fuel Cells (PEMFCs) operate at low temperatures and they are seen as an alternative to internal combustion engines, whose efficiencies are limited by the Carnot cycle. Many researchers have experimentally studied small (~10-50 cm^2), single cell PEMFC systems to understand the behavior and electrochemistry of PEMFC's[1]. Three-dimensional (3-D) electrochemical models have been used to study the distributions of current, temperature, and species mole fractions as a function of the physics and chemistry of these small cells, as also reviewed in Shimpalee et al.[1]. However, the commercial viability of PEMFC systems depends on understanding the mass transport and electrochemistry of larger scale electrodes with reacting area[2, 3] on the order of 200-600cm^2. This paper applies a parallelized 3-D CFD model to a commercial-size PEMFC to examine water management and current distributions for various operating conditions.

Numerical Procedure

Shimpalee and Dutta.[4] and Lee et al.[5] provide a background on the 3-D non-isothermal fuel cell model used in this work. This model provides species and enthalpy source terms to commercial CFD code based on electrochemical calculations. Here, an industrial-size flow-field taken from the patent literature is studied with this model. Figure 1 shows the flow-field model geometry based on the patent of Rock[6]. Figure 2 shows details of trim cells for the bends in the flow channels. The reaction area is 500-cm^2. The model is solved by using parallel algorithms and methods in the STAR-CD commercially available CFD code, the computational time is reduced depending on the number of computing nodes in the cluster.

The focus of this paper is to present and analyze predictions for the distributions of water, temperature, and current density over the 500-cm^2 area of Figure 1 as a function of inlet humidity conditions and heat transfer boundary conditions. The regions where substantial water condensation exists will be discussed. Analogies to distributions calculated for smaller segments of the 500-cm^2 area will be presented. Computational times will be reported and discussed.

Acknowledgements

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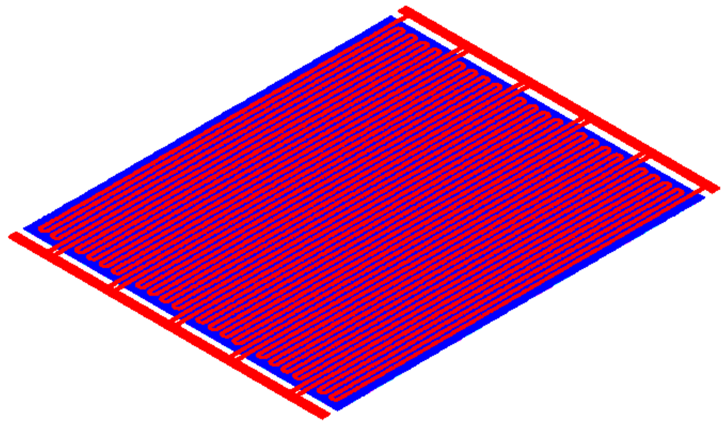

Figure 1. 500-cm^2 PEMFC with flow-field model geometry of Rock[6]'s patent.

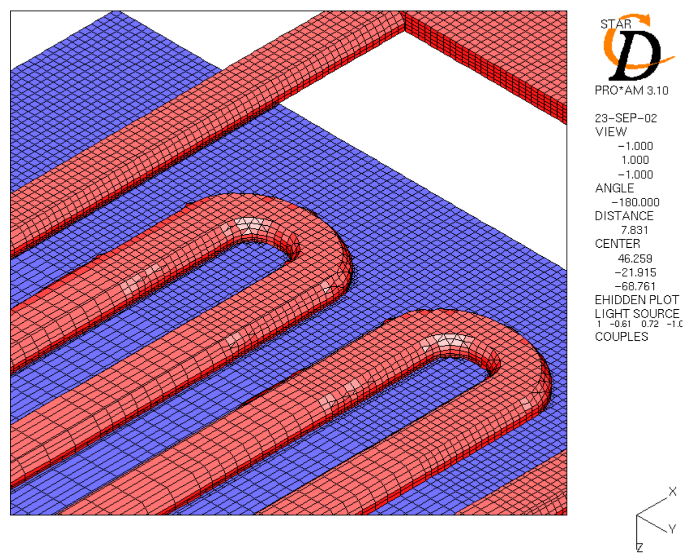

Figure 2. Detail of geometry at bending channel location showing STAR-CD's trim cell capability.

References

1. S. Shimpalee, W-k. Lee, J. Van Zee, and, H. Naseri-Neshat, *in Proceedings of ASME IECE*C, IECEC-2001-10, Savannah, GA (2001).
2. H. Gastieger, and M. Mathias paper #815 presented at the 2002 meeting of the Elecrochemical Society, Salt Lake City, UT, October 2002.
3. M. Mathias, D. Baker, S. Fell, M. Murphy, J. Roth, B. Steidle, M Schoenweiss, paper # 86f presented at the 2002 AIChE Spring National Meeting, New Orleans, LA, March 2002.
4. S. Shimpalee and Dutta, *Numerical Heat Transfer-Part* A, 38, 111-128 (2000).
5. W. k. Lee, S. Shimpalee, J. W. Van Zee, *J. Electrochem Soc.*, In press Nov. 2002.
6. J. A. Rock, U.S. Patent # 6,099,98.