CFD Modeling and Analysis of a Planar Anode Supported Intermediate Temperature Solid Oxide Fuel Cell

N. Lemcoff[1], M. Tweedie[2]

[1]Rensselaer Polytechnic Institute Hartford, Hartford, CT, USA
[2]Enthone, West Haven, CT, USA

Abstract

This study considered a planar anode-supported intermediate temperature solid oxide fuel cell operating on syngas fuel at 750°C. The effects of varying simulated syngas fuel inlet compositions on species distribution, temperature distribution, water gas shift reaction rate, potential for carbon formation and electrochemistry were considered. A 2-D model was developed in COMSOL Multiphysics® software for a fuel cell containing a composite Ni-YSZ anode, YSZ electrolyte, composite LSM-YSZ cathode surrounded by metal interconnects (Fig. 1). The domain included separate defined electrochemical reaction layers on either side of the electrolyte, where chemical reforming and electrochemical reactions simultaneously occurred. Both H_2 and CO electrochemical oxidation were considered along with the internal reforming water gas shift reaction.

The CFD model used the following physics interfaces: Free and Porous Media Flow (Navier-Stokes and continuity equations for momentum transport), Transport of Concentrated Species (Maxwell-Stefan model considering Knudsen diffusion for mass transport), Heat Transfer in Fluids (energy equation for heat transfer), Equation-based model (electrochemical model considering distributed charge transfer over the cell, including Butler-Volmer type kinetics), and a chemical reforming model.

Resulting polarization curves showed good agreement with experimental data (Figure 2). The best performance was found for high fuel inlet concentrations of hydrogen and carbon monoxide with a maximum power density of $720 W/m^2$. Carbon formation in the syngas fueled cell is unlikely to occur when operating from 0.95 to 0.4V. However, at higher applied voltages and higher concentrations of hydrogen and carbon monoxide in the fuel inlet, carbon formation may be possible. Increased amounts of water in the fuel decreased overall performance and increased amounts of N_2 showed better performance than with similar inlet concentrations of either CO_2 or H_2O. Permeability values for the electrodes were also shown to notably affect inlet electrode conditions in the cell.

Reference

M. M. Hussain, X. Li and I. Dincer, "A General Electrolyte-Electrode-Assembly Model for the Performance Characteristics of Planar Anode-Supported Solid Oxide Fuel Cells," Journal of Power Sources, vol. 189, pp. 916-928, 2009.

R. Suwanwarangkul, E. Croiset, E. Entchev, S. Charojrochkul, M.D. Pritzker, M.W. Fowlera, P.L. Douglas, S. Chewathanakup and H. Mahaudom, "Experimental and Modeling Study of Solid Oxide Fuel Cell Operating with Syngas Fuel," Journal of Power Sources, vol. 161, pp. 308-322, 2006.

Figures used in the abstract

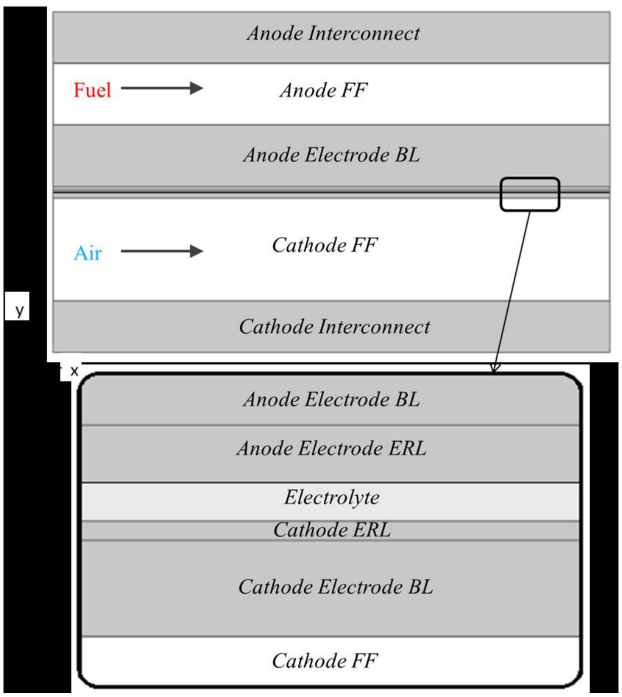

Figure 1: Model domain.

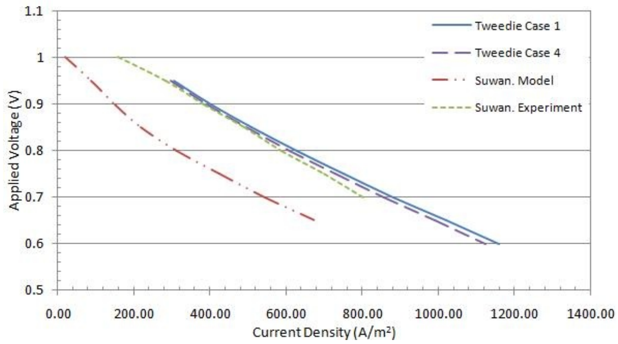

Figure 2: Comparison between Cases 1 and 4 with data from literature.