

# Computational Fluid Dynamics Modeling of Solid Oxide Fuel Cells

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A comprehensive, multi-physics, multi-dimensional model has been developed to simulate solid oxide fuel cells (SOFC). The model fully couples electrochemical kinetics with multi-dimensional gas dynamics and multi-component transport of species. The developed model is a full cell model, including all components of SOFC, flow channels, active and inactive gas diffusion electrodes and electrolyte.

The present model is implemented in a commercially available CFD software, Fluent, using its customization ability via User Defined Functions (UDF). It is able to predict conventional I-V curve (polarization curve) in addition to details of internal processes, such as flow field, species concentrations, potential and current distributions throughout the cell. Calculated polarization curve of an electrolyte-supported SOFC is given in Figure 2. Activation kinetics limit, ohmic limit and mass transfer limit of the polarization curve are clearly seen in this figure. Reactant and product concentrations in the gas channels and porous electrodes are also reported for different cell voltages and operating conditions. The variation of current density along the flow direction is also provided to investigate the effects of mass transfer limitation on performance. It is seen that the current density is decreasing in the flow direction due to the depletion of reactants, especially at higher current densities.

A more complex geometry, as shown in Figure 1, a cross flow type planar electrolyte-supported SOFC has been modeled to investigate three-dimensional effects. Calculated local current density contour of this geometry for a cell voltage of 0.4 V is given in Figure 3. It is clearly seen that the regions facing the channels have much higher current density. This is clearly seen at the zones, where the corresponding anode and cathode channels meet. In those regions, both of the electrodes receive enough reactant, thereby producing higher current. Note that, the reactants can be transported to the regions underneath the current collectors only with molecular diffusion, whereas the regions underneath the gas channels also benefit from the convective mass transport. The reduced transport underneath current collectors results in smaller reactant concentrations, thus smaller current density in these regions. This three-dimensional calculation explicitly illustrates the effect of flow field design on cell performance.

Different SOFC configurations; i.e. anode-supported, cathode-supported and electrolyte-supported, are also simulated and mass transfer limitations of these three different configurations are discussed in detail and compared.

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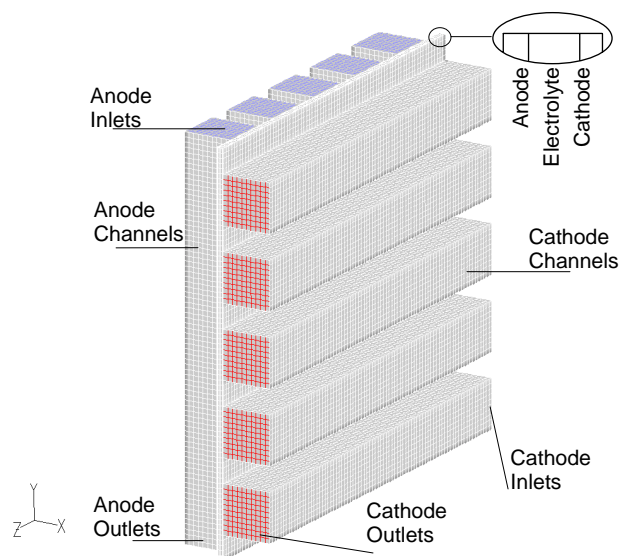


Figure 1 Geometry and generated mesh of five channel electrolyte supported cross-flow SOFC geometry

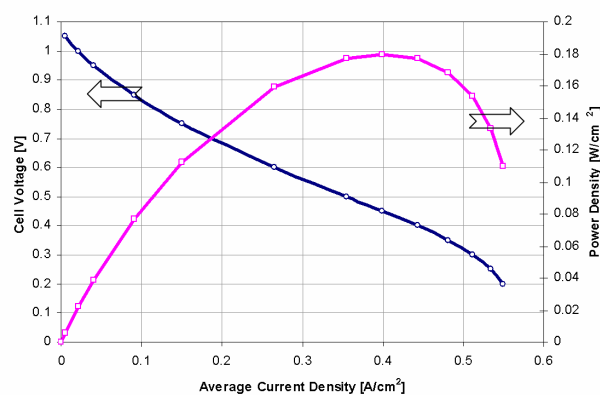


Figure 2 Calculated Polarization and Power Density Curves of Electrolyte-Supported SOFC (Anode and Cathode Stoichiometry, 1.5 and 2.0, respectively, operating temperature, 1000°C)

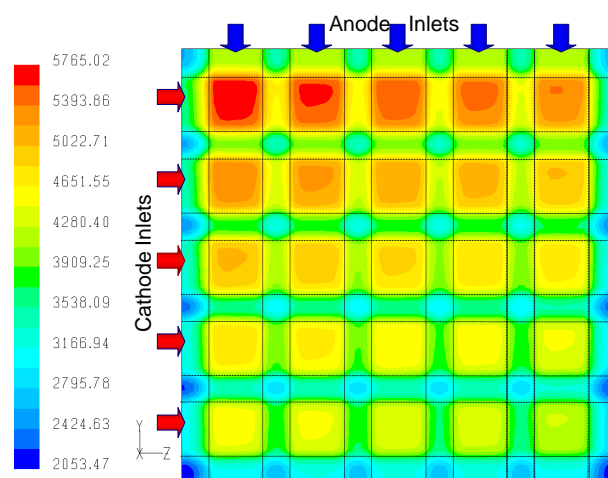


Figure 3 Current Density Distribution of 5-Channel Cross-Flow Electrolyte Supported SOFC (Anode and Cathode Stoichiometry, 1.5 and 2.0, respectively, Operating Temperature, 1000°C, Cell Voltage 0.4V)

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