Numerical modelling of a serpentine channel SOFC for elevated pressure applications

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Introduction
Solid Oxide Fuel Cell (SOFC) is an electrochemical device that directly converts the chemical energy into the electrical energy through electrochemical reaction. SOFC is one of the promising alternatives to conventional power plants due to its higher efficiency, fuel flexibility, and possibilities of combined heat and power generation due to its high operating temperature.

Figure 1: Schematic Diagram of an SOFC

Materials and Geometry
Components
Electrolyte: 8-YSZ, Cathode: Ni/YSZ, Anode: LSM
Working Fluids
Fuel: Hydrogen, Oxidant: Air.
Geometry Type
Segmented Serpentine channel SOFC

Figure 2: Serpentine plate geometry

Modelling Methodology and Validation
Physics of mass, momentum, heat transfer have coupled with cell electrochemistry using following governing equations:

Free fluid flow in channels: Navier Stokes Equation
Subsurface Flow in Electrodes: Brinkman Equation
Heat Transfer: Generalised Energy Equation
Electrochemistry: Nernst Equation, Butler-Volmer equation

The model is uniformly meshed using \( \sim 10^6 \) cuboidal elements customized to be finer near the reacting interfaces. A direct solver, PARDISO of COMSOL Multiphysics is employed by setting a relative tolerance of \( 10^{-5} \) to solve the equations with suitable boundary conditions[1].

Results
Velocity profile in pressurised SOFC:

Figure 3: velocity profile at pressurised condition: Cathode (left); Anode (right)

Spatial Distribution of Hydrogen along the flow channel: Figure 4 depicts the hydrogen distribution along the serpentine flow channel at ambient pressure condition as well as at pressurised condition. It shows that at elevated pressure, hydrogen concentration is more uniformly distributed; that also helps to predict the uniform current generation at elevated pressure. Non-uniformity of current density in plate is one of the major cause of cell depletion; which can be avoided by pressurizing the system.

Distribution of Temperature in the SOFC:

Figure 5: Temperature profile of SOFC model at elevated pressure

VI characteristics:

Figure 6: Variation of VI characteristics with pressure: 1073 K (left); 1023 K (right)

References


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