Heat Transfer Modelling of Single High Temperature Polymer Electrolyte Fuel Cell using COMSOL Multiphysics®

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INTRODUCTION
Polymer Electrolyte Fuel Cell (PEFCs) are the best available option for automotive drive train applications. Among PEFCs, High Temperature PEFC is actively being considered as an alternative to Low Temperature PEFC due to:
- The HT PEFC operates in the temperature range of 120 – 180°C.
- This could possibly mean that temperature of exhaust coming out from HT PEFC could be in the range of 150°C.
- Less complex cooling system design.
- Higher tolerance to CO.
- In a HT PEFC ~ 50% of the chemical energy supplied by the fuel is converted to thermal energy.
- Possibility of CHP (Combined Heat & Power) application

Aim & Challenges
Aim:
To study and compare the effect of parallel & serpentine flow field designs on temperature distribution in HT PEFC.

Challenges:
- To extract maximum heat from the fuel cell.
- To maintain the temperature of the fuel cell within limits (max 473 K).

APPROACH & COMPUTATIONAL METHODOLOGY
In this work a 3D model of a single HT PEFC with all components (membrane, cathode, anode & bipolar plate with flow field) was modelled for heat transfer

Heat generation terms in Fuel Cell:
\[ \rho \left[ \left( \frac{\partial}{\partial t} + \mathbf{u} \cdot \nabla \right) \mathbf{u} \right] - \nabla \cdot \left( \mu \nabla \mathbf{u} \right) - \nabla \cdot \left( \frac{\mu}{\rho} \mathbf{u} \right) \mathbf{u} = \nabla \cdot \left( \frac{\dot{Q}}{\rho C_p} \right) + \frac{\dot{Q}_{\text{irrev}}}{} \]

Total internal heat applied to model = 0.32 W cm^{-2}

Dimensional Cutting Plane

Figure 3: HT PEFC with parallel flow field

Figure 4: HT PEFC with serpentine flow field

Figure 5. Temp. distribution with PARALLEL flow field for different Air/ H2 flow combinations

Figure 6: Temp. distribution with SERPENTINE flow field for different Air/ H2 flow combinations

Energy Equation
\[ \rho C_p \mathbf{u}. \nabla T = \nabla \cdot (k \nabla T) + Q \]

Governing Equations for Conjugate Heat Transfer:
- Momentum Equation
\[ \rho \left( \mathbf{u}. \nabla \right) \mathbf{u} = \nabla \cdot \left( -p I + \mu \left( \nabla \mathbf{u} + (\nabla \mathbf{u})^T \right) \right) - \frac{2}{3} \mu \nabla \cdot \mathbf{u} + \mathbf{F} \]

Continuity Equation
\[ \nabla \cdot (\rho \mathbf{u}) = 0 \]

Energy Equation
\[ \rho C_p \mathbf{u}. \nabla T = \nabla \cdot (k \nabla T) + Q \]

EQUATIONS APPLICABLE IN RESPECTIVE DOMAINS

DOM 1 = SOLID
Energy Equation

DOM 2 = FLUID FLOW
Momentum + Continuity + Energy

RESULTS

CONCLUSIONS

- Heat transfer modelling of single cell provides information on temperature distribution within the fuel cell.
- Relatively uniform temperature profile with parallel flow field
- Serpentine flow field leads to extremely large temperature distribution
- Aids in choosing cooling methodology for fuel cell based on flow field design
- Higher velocities of gas streams leads to lower temperature distribution in the Fuel Cell
- Basis for scaling up the model to stack level for understanding cell to cell thermal coupling

REFERENCES