Heat Transfer Modelling of Single High Temperature Polymer Electrolyte Fuel Cell (HT PEFC) Using COMSOL Multiphysics®

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Abstract

The HT PEFC operates in the temperature range of 120-180 deg C. In a HT PEFC almost 50% of the chemical energy supplied by the fuel is converted to thermal energy. This could possibly mean that the temperature of the exhaust coming out from the HT PEFC could be in the range of 150 deg C. However the key challenge is in extracting maximum heat available from the fuel cell and at the same time maintaining the fuel cell temperature within desired limits. The extracted heat could either be used in a CHP (Combined Heat & Power) or CCHP (Combined Cooling Heat & Power) application. The fuel cell temperature needs to be maintained at an appropriate level to obtain maximum performance from the fuel cell and to prevent degradation of the fuel cell. In the case of HT PEFC the limit is 200 deg C above which performance of the membrane degrades.

In this paper a 3D model of a single HT PEFC with all the components (membrane, cathode, anode & bipolar plate with flow field) was modelled for heat transfer. The source of heat within the fuel cell is the internal heat generated from the electrochemical reactions. The corresponding heat source terms used in the model are tabulated below

Joule Heat - Occurs in membrane and modelled as Volumetric heat source
Entropic & Irreversible heat - Occurs in the catalyst layer between cathode & membrane and modelled as boundary heat source

All the heat source terms are a function of operating current density of the fuel cell and hence vary as the current density term varies. However, in practical applications the HT PEFC is operated at a current density of 0.43 A cm-2 and at a voltage of 0.7 V. Hence, the heat source terms are calculated for this particular current density alone. The geometry of the flow field used in the model is shown in Figure 1. Heat transfer studies using COMSOL Multiphysics® is extremely useful for analysing the temperature distribution within the fuel cell components and also to decide on an efficient thermal management strategy for maintaining the cell temperature within desired limits.

In this study a parametric sweep of the reactant flows was conducted to analyse if forced convection was sufficient to keep the cell within temperature limits. This COMSOL Multiphysics® model provides data on what stoichiometric ratios of the reactant streams are

needed for proper thermal management of the fuel cell and also provides a basis for calculating the amount of heat available from the fuel cell exhaust. The effect of different flow fields on temperature distribution within the fuel cell can be analysed. Figure 2 shows the temperature distribution across the entire fuel cell for the parallel flow field and serpentine flow field and Figure 3 shows the temperature distribution in the X-Y plane. The author plans to scale the single cell model to the 3D stack level to analyse the temperature distribution within the fuel cell stack.

Reference

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3. Harikishan Reddy, E. and S. Jayanti, Thermal management strategies for a 1 kWe stack of a high temperature proton exchange membrane fuel cell. Applied Thermal Engineering, 2012. 48(0): p. 465-475.

Figures used in the abstract

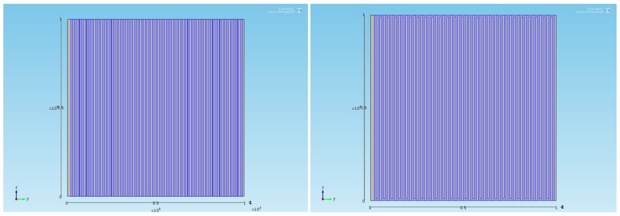
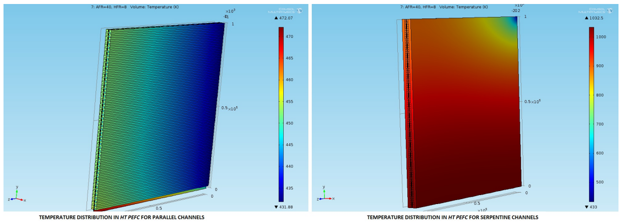


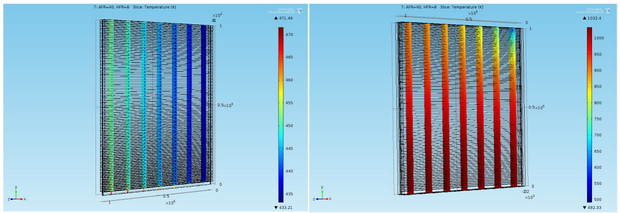
Figure 1: Flow field patterns- parallel & serpentine



TEMPERATURE DISTRIBUTION IN *HT PEFC* FOR PARALLEL CHANNELS

TEMPERATURE DISTRIBUTION IN *HT PEFC* FOR SERPENTINE CHANNELS

Figure 2: Temperature distribution across entire Fuel Cell



TEMPERATURE DISTRIBUTION IN X-Y PLANE FOR *PARALLEL* CHANNELS

TEMPERATURE DISTRIBUTION IN X-Y PLANE FOR *SERPENTINE* CHANNELS

Figure 3: Temperature distribution along X-Y plane