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Thermal Analysis of Hydrogen Fuel Cell Inter Cooling by using Heat Exchanger

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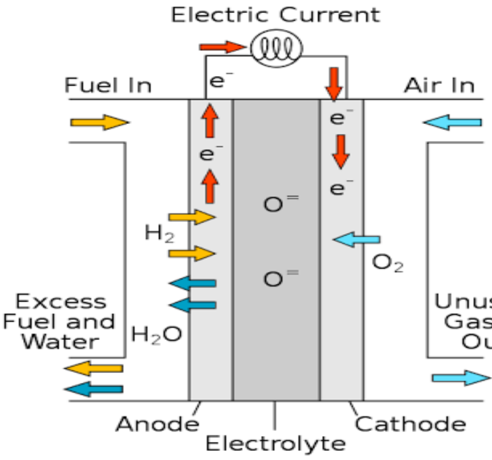
***Abstract* - In this hydrogen fuel cell is to convert H_2O into HHO .So the process is a high heat process. This will causes damages on a cylinder wall such a sludge and scaling. So the cylinder must requires a cooling system (heat exchanger) The moderated plate type heat exchanger should be solve this problem .In this case the specially fabricated heat exchanger separates the two bipolar plates and also absorbs the heat generated in the liquid medium. The heat exchanger is insulated both sides and strips outer side of the fuel cell cylinder to expose internal heat of the liquid medium.**

INTRODUCTION

Fuel cells are devices that produce electricity through electrochemical reactions. In a insulated heat exchange membrane fuel cell (IHEFC), a membrane separates oxidation and reduction half reactions. Schematically shows the basic construction of a IHEFC. The fuel is hydrogen gas and the oxidant is ambient air or pure oxygen. The only byproducts of this reaction are heat and air. Considering their high energy conversion efficiency, zero emission potential, low noise and potential use of renewable fuels, fuel cells are considered as future devices for mobile, stationary, and portable power applications.

However, IHEFC systems are not currently cost effective; increasing their efficiency for transportation and stationary applications can improve their commercialization.

Operation of a IHEFC is a complex process and includes transport of mass, momentum, energy, species and charges that take place simultaneously. Different parts of a IHEFC are comprised of current collectors, anode and cathode flow channels, gas diffusion layers (GDLs), catalyst layers and the membrane.



Basic construction of a typical IHE fuel cell

During the operation of a IHEFC, hydrogen molecules are supplied at the anode and split into protons and electrons. The polymeric membrane conducts protons to the cathode while the electrons are pushed round an external circuit and a current is generated from anode side to cathode side via electric load. Oxygen (form air) is consumed in the cathode side and reacts with the hydrogen ions, producing air and heat. Fuel cells are still undergoing intense development, and the combination of new and optimized materials, improved product development, novel architectures, more efficient transport processes, and design optimization and integration are expected to lead to major gains in performance, efficiency, reliability, manufacturability and cost-effectiveness.

LITERATURE REVIEW

The terms “poll” and “survey” are used interchangeably in this report. There is, however, a distinction made between scientific polls (or surveys) and non-scientific polls (or surveys). A scientific survey is carefully constructed to provide statistically representative results within a known margin of error. A non-scientific survey lays no claim to accuracy; it might simply solicit responses from anyone who happens upon the poll, is interested in providing an opinion, and has a mechanism for responding. In order to assess the current understanding of hydrogen and fuel cells technologies and applications (information important to developing successful education strategies), the HFCIT program plans to conduct scientific surveys of four target audiences. Surveys of the general public, the educational community, governmental agencies, and potential large users will provide a baseline knowledge assessment for each of these groups.

DOE will conduct identical surveys in 2004, 2007, and 2010 in order to obtain an accurate understanding of whether knowledge and opinions about hydrogen technologies have changed over time. Because consistency of methodology and approach are critical, the survey instrument developed for use in 2004 will be used with the same target audiences and will be administered using precisely the same methodology in 2007 and 2010.

The purpose of this literature review is to examine the literature and summarize the results of surveys that have been conducted in the recent past concerning the existing knowledge of hydrogen, hydrogen technologies, and the hydrogen economy.

This literature review covers both scientific and, to a lesser extent, non-scientific polls. Such information can enlighten the HFCIT knowledge assessment activity and will be helpful in designing the HFCIT survey. The information gained in this literature review does not, however, replace the need for the HFCIT surveys.

STACK COOLING METHODS: OVERVIEW

There are different cooling methods that can be used in fuel cell systems to maintain a constant temperature. These include heat spreaders, cooling with cathode air flow, cooling with separate air flow, air cooling, and cooling with antifreeze/coolant.

1. PASSIVE METHOD
2. ACTIVE METHOD

PASSIVE METHOD

Passive cooling refers to design features used for cooling without power consumption.

ACTIVE METHOD

Active cooling refers to design features used for cooling with power consumption.

AIR COOLING

For hydrogen IHEFCs larger than 10 kW, it is generally necessary to use air cooling. Units below 2 kW can be air cooled, and cells between 2 kW and 10 kW need a careful choice regarding whether air or air cooling should be used. Air cooling requires a more complex design: the temperature and pressure of the cooling air must be monitored and the flow of cooling air must be supplied by a air pump. Stack cooling in direct methanol fuel cell is relatively simpler, since increasing circulation of dilute methanol solution at the anode could remove more waste heat from the stack.

MODEL DEVELOPMENT

In this chapter, first, we introduce the transport phenomena in IHEFCs with governing equations that are solved in our model and the assumptions that were considered. Finally, we validate the results for temperature distribution with experiments.

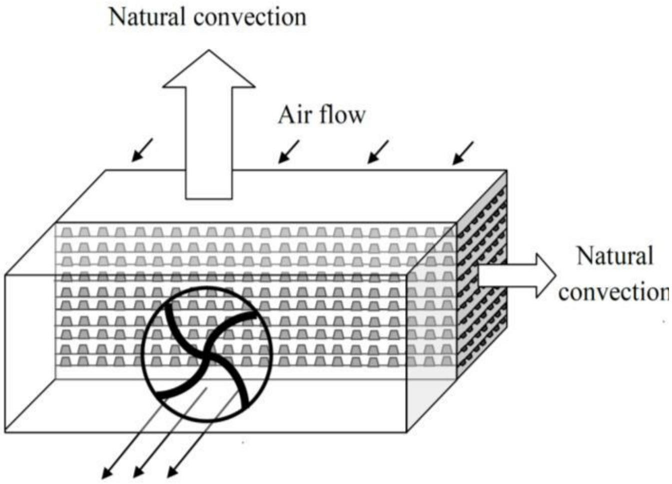
Transport phenomena in IHEFCs

The cathode side of the MEA, shown schematically in provides a good illustration of the complex coupling between various transport phenomena in IHEFCs. The MEA consists of a insulated heat exchange membrane sandwiched between catalyst and gas diffusion layers, with the latter two components essentially forming the electrode. This electrode is a buffer zone that facilitates a number of process phenomena in a fuel cell, as it is done in this study.

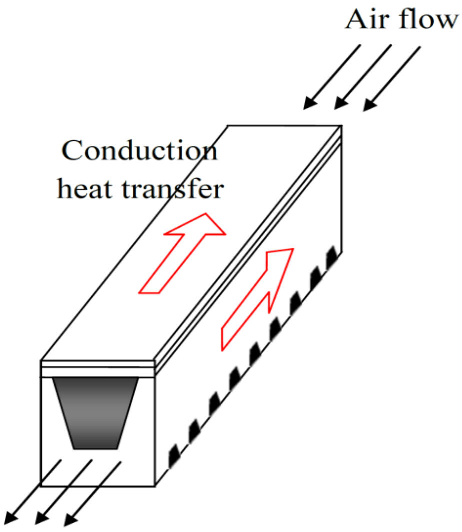
Heat Transfer in a Fuel Cell Stack

The schematic of an air-cooled stack and a single channel and different modes of heat transfer. Heat transfer modes in a fuel cell stack include:

1. Natural convection from the outer surface of the stack to ambient air.
2. Forced convection in the channels and porous layers.
3. Conductive heat transfer in the solid phase, i.e. bipolar plates, GDLs, and catalyst coated membrane.
4. Radiation heat transfer from the stack surface.



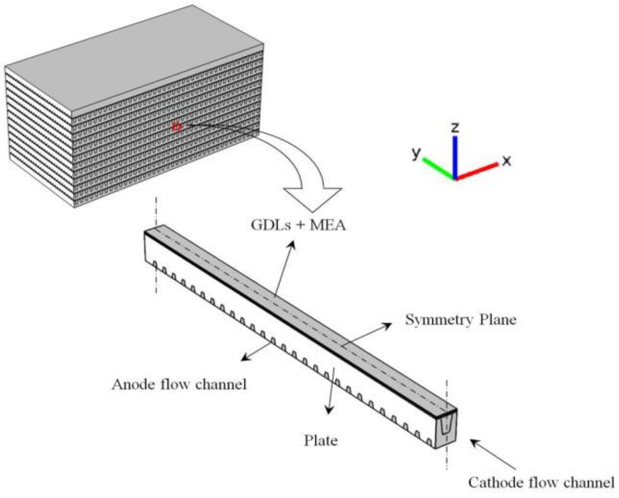
Schematic of heat transfer in an air-cooled stack



Schematic of heat transfer in a single channel

As explained previously, it is desirable to operate the fuel cell system at a temperature slightly below the maximum allowable temperature. Therefore, predicting the maximum temperature in a stack is of high importance. Intuitively, one can predict that the maximum temperature occurs somewhere in the central cells of a fuel cell stack and the other cells that are closer to the outer surface experience a lower temperature as a result of heat transfer from the outer surface. Similarly, in a single cell we expect that the temperature in the central channel will be higher than the other channels. Since one of the main interests of this research is to predict the maximum temperature in a stack, the complete stack is not modeled.

Instead, we have considered the central cathode channel with plate and GDLs surrounding it in the central cell, which is expected to experience the maximum temperature in the entire stack. Taking advantage of symmetry in the fuel cell geometry, the computational domain is half of a single cathode channel as sketched.



3D schematic of a fuel cell stack and a cathode channel, the computational domain

Since air-cooled stack is studied here, we should include the air domain before entering the cathode channel and after exiting the outlet. Otherwise, the heat transfer from the end walls cannot be accurately captured in the model. Even considering an equivalent convective heat transfer coefficient does not lead to the same results as when including the air domain in the inlet and outlet. A schematic of the computational domain including inlet and outlet air. In the present study, we have considered heat transfer in the entire domain and laminar fluid flow in the oxidant channel. The convective heat transfer in the hydrogen channels and porous gas diffusion layers is negligible due to the relatively low velocity of fluid in these regions.

Also, considering the central channel as the computational domain, it can be shown that radiation heat transfer is negligible since the temperature is not high and also the surface area of the ends are small compared to the total surface area. The model inputs are current density, cell voltage, and inlet air temperature and velocity.

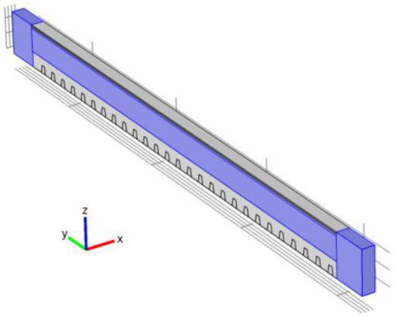
Summary of Assumptions

The following is a summary of the assumptions we made to model the fluid flow and heat transfer in an air-cooled IHEFC stack. Each of these assumptions is explained in the relevant sections.

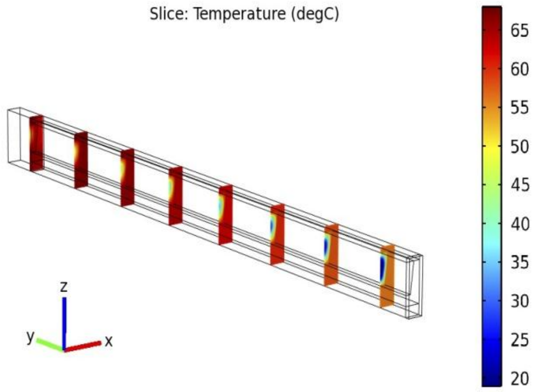
Continuous, steady state, laminar (Re<800), incompressible flow (Ma<0.3) was assumed. The central channel was considered to be insulated. Convective heat transfer in anode channel and GDL was neglected. Constant thermo-physical properties were assumed for the solid phase. Radiation heat transfer was neglected (based on scale analysis). Uniform heat generation in MEA was considered. LHV was used for heat generation.

Mesh Independency

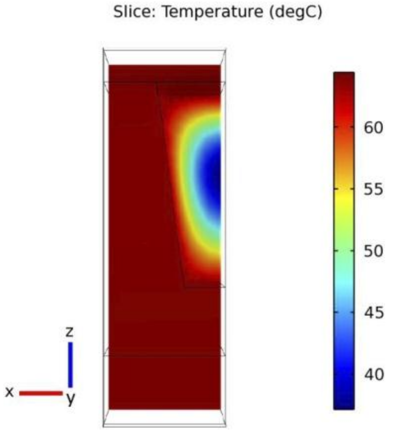
Three different amount of mesh elements- 3.5×105, 7.0×105 and 1.4×106- were implemented and compared in terms of local temperature, velocities, and pressure to ensure a mesh independent solution. We found that the mesh size of around 7.0×105 gives approximately 1% deviation compared to the mesh size of 1.4×106; whereas, the results from 7.0×105 mesh elements deviate up to 7% as compared to those from the finest one. Therefore, a mesh of around 7.0×105 elements was sufficient for the numerical investigation purposes: a fine structured mesh near the wall to resolve the boundary layer and an increasingly coarser mesh in the middle of the channel in order to reduce the computational cost.



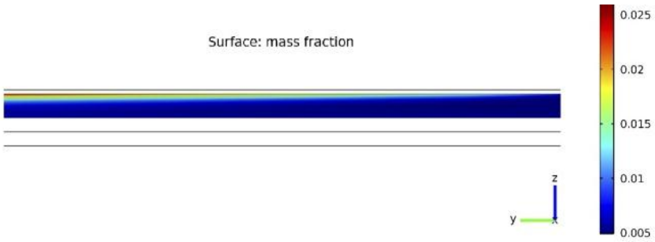
Computational domain for the IHEFC thermal model with inlet and outlet air domain.



Temperature contours in the middle cross section of the channel



Temperature contours in eight slices from inlet to outlet of the channel



Air vapour mass fraction distribution in cathode channel

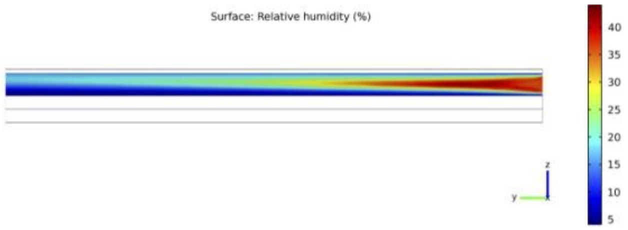
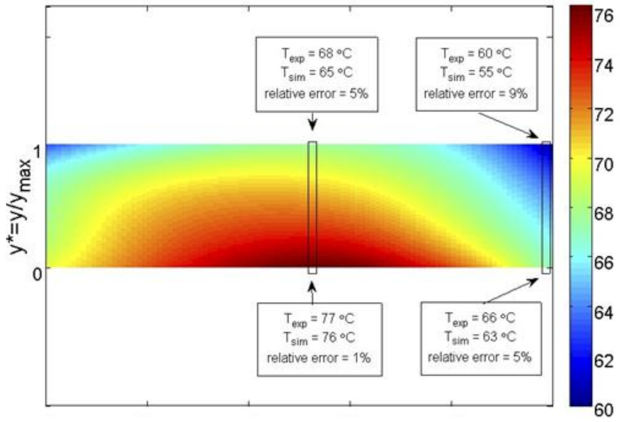


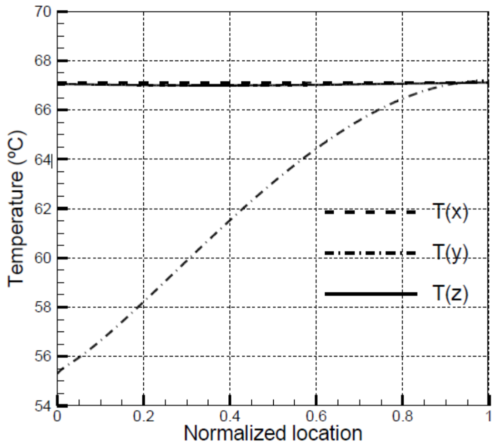
Figure10.5 Relative humidity distribution in cathode channel

RESULTS AND DISCUSSION

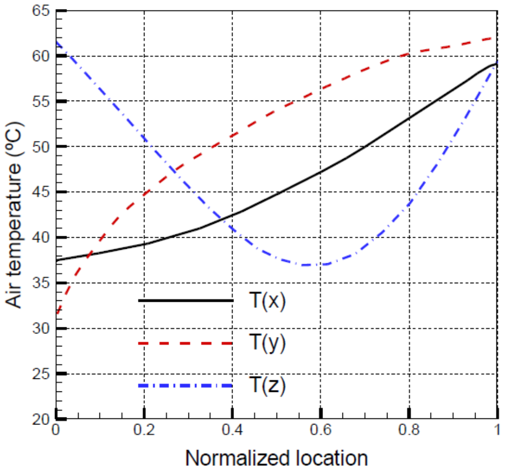
Figure shows the temperature contours in the middle cross section of the channel. A uniform temperature distribution in the solid region is observed, whereas relatively high temperature gradient exists in the flow channel. temperature contours are shown in different sections along the channel. For better description of temperature distribution in the solid and fluid regions.



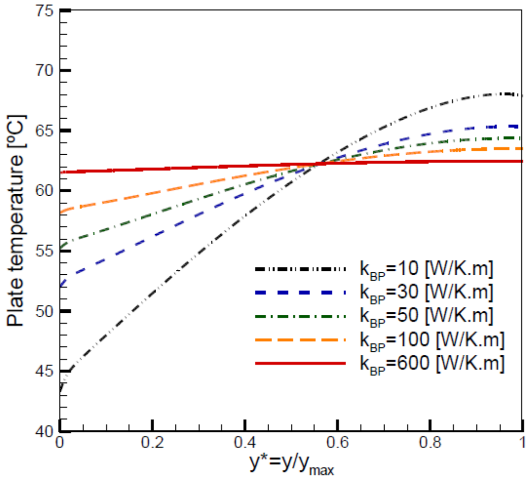
Bipolar plate configuration, (b) Temperature distribution in one plate, interpolated using experimental data points. The experimental and numerical values for the inlet and outlet temperatures are compared for the central and side channels



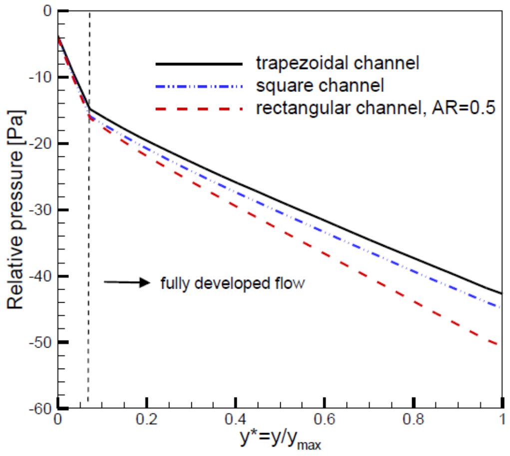
Temperature variation in different directions in bipolar plate



Temperature variation in different directions in air



Different impact of in-plane and through-plane bipolar plate thermal conductivity on temperature distribution along the channel



Oxidant relative pressure in flow direction for trapezoidal, square, and rectangular channel cross-sections.

CONCLUSIONS

In order to develop techniques and strategies for cooling and thermal management of IHEFCs, numerical modeling is a strong method that has been much considered in recent years. In the present work, a three-dimensional thermal model is developed to predict the temperature distribution in a IHEFC. The proposed model can be used for design and optimization of cooling devices for IHEFC systems. This model provides the maximum temperature in an air-cooled IHEFC stack, without considering the whole stack as the solution domain.

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