Effect of Cathode Oxygen Concentration in High Temperature Single Flow Channel PEM Fuel Cell

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***Abstract*— The design and various operating parameters are the two key factors which mostly affect the performance of any Proton Exchange Membrane Fuel Cells (PEMFC). Accumulation of water droplets on the cathode side is minimizing the penetration of hydrogen and oxygen gas in between the gas diffusion layer. So that the complete elimination of water droplet on the cathode side is the significant one to improve the performance of PEMFC. In this research single flow channel, high temperature Proton Exchange Membrane Fuel Cell is selected to investigate the effect of the cathode oxygen concentration for the five various operating temperatures by using commercial analysis software. The result shows that the Proton Exchange Membrane Fuel Cell with an operating temperature of 463K gives the better cathode oxygen concentration among the other three operating temperatures.**

***Keywords*— *High temperature PEMFC, single flow channel, cathode oxygen concentration, cell voltage*.**

I. Introduction

With an increasing awareness of environmental concerns and a desire for energy independence, the development of renewable and clean energy sources has become the focus of significant research activity. Hydrogen will play a major role in fulfilling the global energy demands in future [1]. There are several compelling technological and commercial reasons for operating H2/air PEM fuel cells at temperatures above 100 °C. Rates of electrochemical kinetics are enhanced, water management and cooling is simplified, useful waste heat can be recovered, and lower quality reformed hydrogen may be used as the fuel [2]. By studying the influences of water and thermal management on two-phase flow, it is found that two-phase flow characteristics in the cathode depend on the current density, operating temperature, and cathode and anode humidification temperatures [3]. Safe and reliable operation of a fuel cell requires proper management of the water and heat that are produced as by-products. Most of the current models for the cell used for an analysis of the fuel cell system are based on the empirical polarization curve and neglect the dynamic effects of water concentration, temperature and reactant distribution on the characteristics. The new model proposed in this paper is constructed upon the layers of a cell, taking into account the following factors: (a) dynamics in temperature gradient across the fuel cell; (b) dynamics in water concentration redistribution in the membrane; (c) dynamics in proton concentration in the cathode catalyst layer; (d) dynamics in reactant concentration redistribution in the cathode GDL [4].

A three dimensional model of a proton exchange membrane fuel cell (PEMFC) operating with a polybenzimidazole (PBI) membrane is presented. This model is an improvement on the previous three models developed for this type of PEM fuel cell. The model accounts for all transport and polarization phenomena and the results compare well with published experimental data for the same sets of operating conditions. The model predicts the oxygen depletion, which occurs in the catalyst area under the ribs, and a temperature rise of up to 20 K at a power density of 1000 W m−2 can be expected depending on operating conditions [5]. In this work, a three-dimensional half-cell model for a 50 cm2 high temperature polyelectrolyte membrane fuel cell (HTPEMFC) has been implemented in a Computational Fluid Dynamics (CFD) application. It was solved for three different flow channel geometries: 4-step serpentine, parallel and pin-type. The model predicts that parallel flow channels present a significant lower performance probably due to the existence of preferential paths which makes the reactant gases not to be well distributed over the whole electrode surface. This results in lower output current densities when this geometry is used, especially at high oxygen demand conditions. This behavior was also detected by experimental measurement. Serpentine and pin-type flow channels were found to perform very similarly, although slightly higher limit current densities are predicted when using serpentine geometry. Inlet flow rate as well as temperature influence were also studied. The model predicts mass transfer problems and low limit current densities when the fuel cell is fed with small oxygen flow rates, whereas no differences regarding average flow rates are noticed if it is over increased. Better fuel cell performance is predicted while temperature grows as it could be expected [6]. A pseudo-homogeneous model for the cathode catalyst layer performance in PEM fuel cells is derived from a basic mass–current balance by the control volume approach. The model considers kinetics of oxygen reduction at the catalyst/electrolyte interface, proton transport through the polymer electrolyte and oxygen diffusion through porous media. The governing equations, a two-point boundary problem, are solved using a relaxation method. The numerical results compare well with our experimental data. Using the model, influences of various parameters such as over potential, proton conductivity, catalyst layer porosity, and catalyst surface area on the performance of catalyst layer are quantitatively studied. Based on these results, cathode catalyst layer design parameters can be optimized for specified working conditions [7].

II. Modeling

Complete three dimensional model of the high temperature single flow channel PEM fuel cell is created using commercial modeling software package. The various design inputs like channel length, channel height, channel width, rib width and membrane thickness etc., are considered to create the isometric model. The three dimensional model is shown in figure.1. Meshing of the above model is done by using the commercial analysis software. The entire model is meshed with fine mesh elements for getting the better numerical results. Complete mesh is shown in figure.2.

III. Analysis

Numerical computational analysis of the high temperature single flow channel PEM fuel cell is begins with very much characterized limit conditions utilizing the "express summon" and this order execute the three dimensional geometry at distinctive geometrical parameters spaces. The determination of distinctive channels was finished by execute the “choice areas" (delta, outlet, GDL, limit conditions, no of channels, and so on.). After that material properties were doled out to "PEMFC including areas" to execute and introduce the liquid transportation, mass transportation phenomena, and permeable media. These every single material properties areas were utilized to execute the permeable media of the "PEMFC space" utilizing the permeable network system. Next level moves with lattice of the made geometry model. To improve the outcomes from the model (force thickness) whole model was fit by utilizing "cross section creation space" with connected tedra-hectral lattice. After that "study summons" were instated to allocate the obliged yield parameters like (Fluid stream, Oxygen & Hydrogen mass division). At long last diverse yield parameter results were acquired by utilizing "figure including area" as far as form plot.

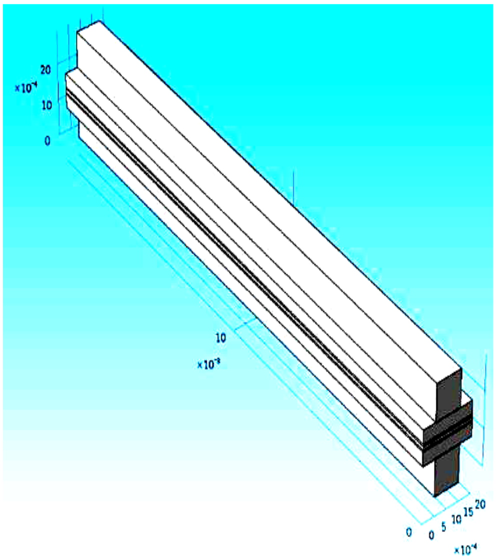

Fig.1. Isometric Model

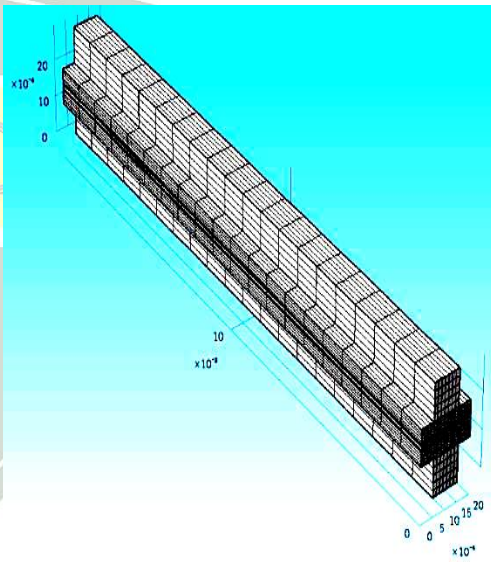

Fig.2.Mesh model

IV. Results & Discussions

The following numerical computational results are obtained from commercial software package for various operating parameters and four different operating temperatures.

A. *Oxygen concentration on cathode side for 463K*

Figure.3 shows the cathode oxygen concentration of high temperature single flow channel PEM fuel cell at an operating of temperature 463K. The figure also shows the effective distribution of oxygen throughout the channel length of the cell. The concentration of oxygen is higher at the inlet and lower distribution at the outlet of the channel of 2.6321 and 0.0709 mol/m3 respectively. Besides compared with other operating temperatures PEM fuel cell with 463K gives the maximum cathode oxygen concentration inside the cell (2.6321 mol/m3).

B. *Oxygen concentration on cathode side for 473K*

Figure.4 shows the cathode oxygen concentration of high temperature single flow channel PEM fuel cell at an operating of temperature 473K. The figure also shows the effective distribution of oxygen throughout the channel length of the cell. The concentration of oxygen is higher at the inlet and lower distribution at the outlet of the channel of 2.5765 and 0.0706 mol/m3 respectively.

C. Oxygen concentration on cathode side for 483K

Figure.5 shows the cathode oxygen concentration of high temperature single flow channel PEM fuel cell at an operating of temperature 483K. The figure also depicts the effective distribution of oxygen throughout the channel length of the cell. The concentration of oxygen is higher at the inlet and lower distribution at the outlet of the channel of 2.5232 and 0.0701 mol/m3 respectively.

D. Oxygen concentration on cathode side for 493K

Figure.6 shows the cathode oxygen concentration of high temperature single flow channel PEM fuel cell at an operating of temperature 493K. The figure also depicts the effective distribution of oxygen throughout the channel length of the cell. The concentration of oxygen is higher at the inlet and lower distribution at the outlet of the channel of 2.4720 and 0.0698 mol/m^3 respectively.

E. Effect of Oxygen concentration on cathode side for all temperatures

Figure.7 shows the cathode oxygen concentration of high temperature single flow channel PEM fuel cell for all operating of temperatures 463, 473, 483 and 493K respectively. It also depicts the effective distribution of oxygen throughout the channel length of the cell is dependent on operating temperatures. It is also observed that the oxygen distribution is gradually decreased with the increased operating temperatures. So it is clear to said that the effective oxygen distribution is also depends upon the operating temperatures. The PEM fuel cell with an operating temperature of 463K yields the better oxygen concentration of (2.6321 mol/m^3) respectively.

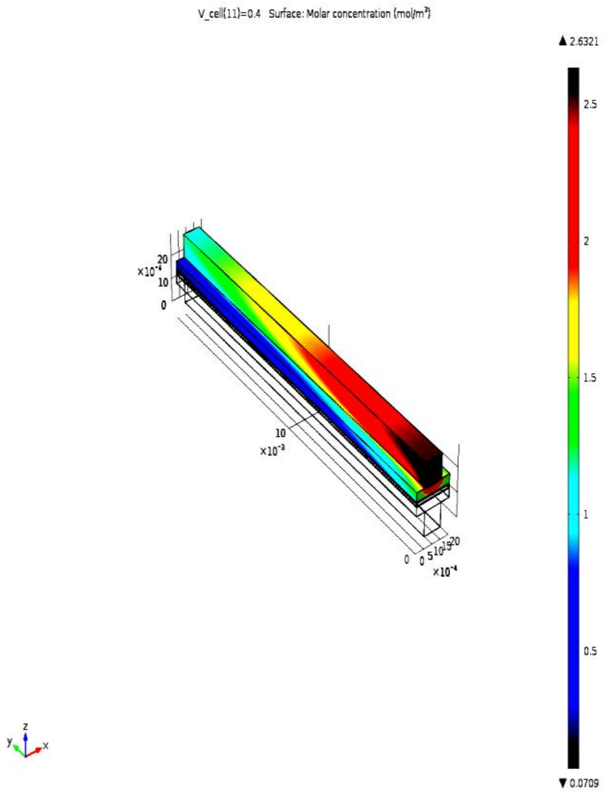

Fig.3. Cathode oxygen concentration at 463K

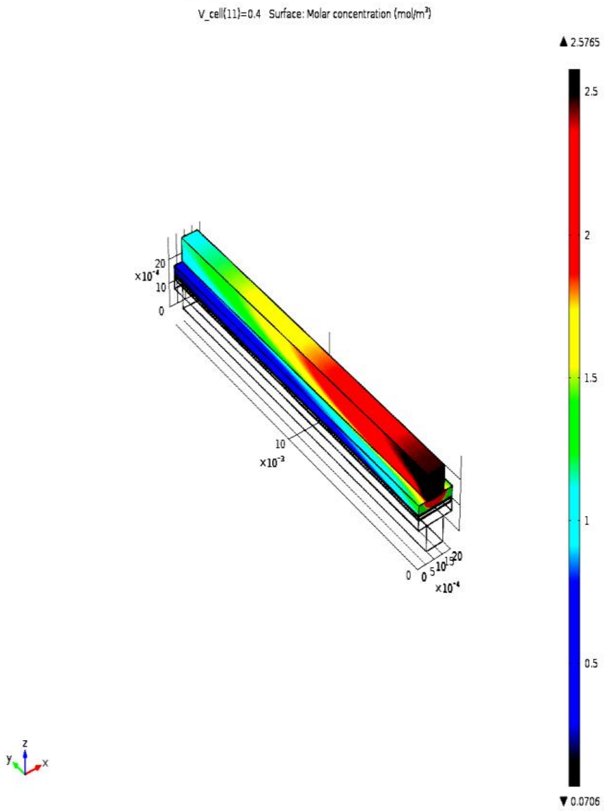

Fig.4. Cathode oxygen concentration at 473K

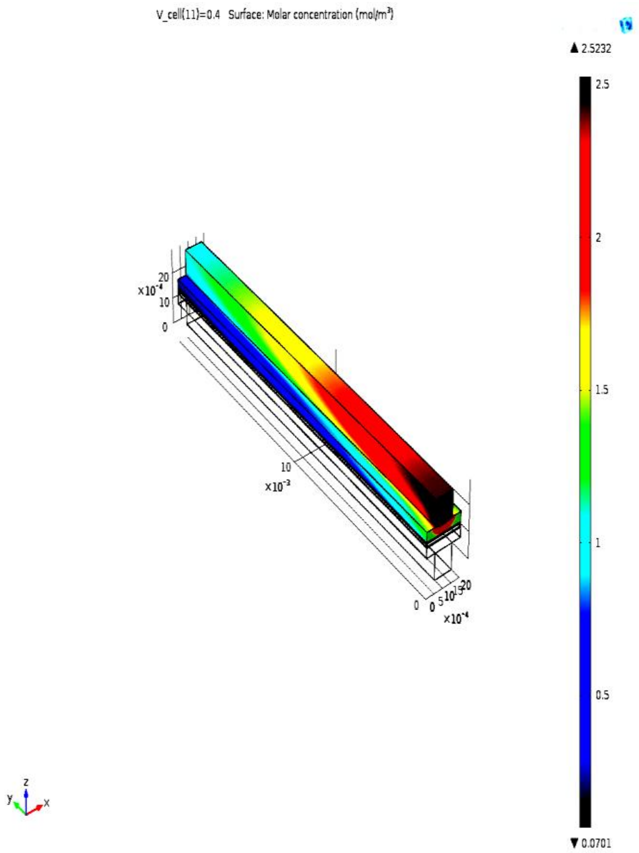

Fig.5. Cathode oxygen concentration at 483K

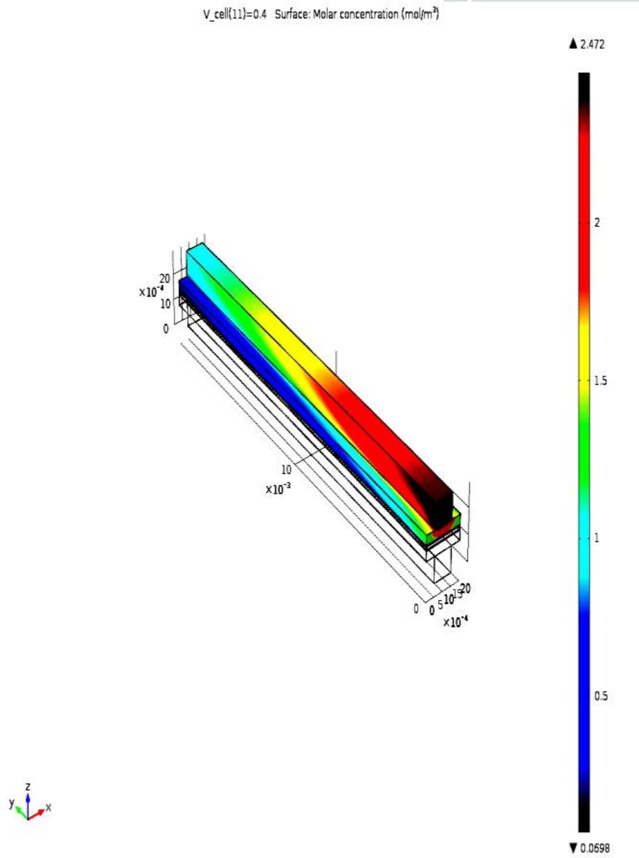

Fig.6. Cathode oxygen concentration at 493K

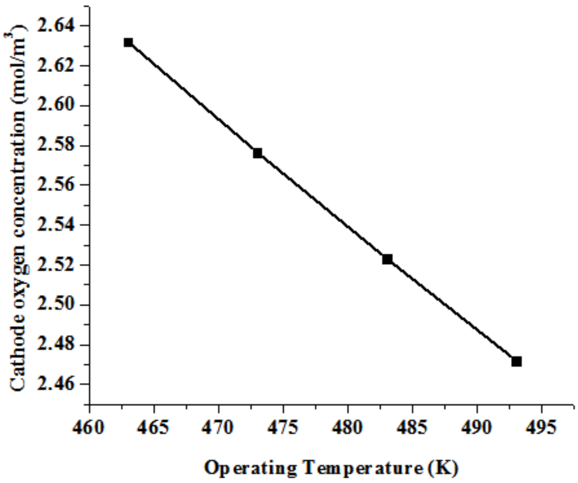

Fig.7. Effect of reactant cathode oxygen concentration at various operating temperatures

V. SUMMARY

The three dimensional model of high temperature PEM fuel cell with single flow channel configuration with four different operating temperatures (463K, 473K, 483K & 493K) were analysed to investigates the effect of cathode oxygen concentration using commercial computational software. From this numerical analysis high temperature PEM fuel cell with single flow channel configuration operating at an operating temperature of 463K yields the maximum oxygen concentration (2.6321 mol/m^3) compared with three operating temperatures.

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