Numerical Investigation of Anode Hydrogen Concentration in High Temperature PEM Fuel Cell with Single Flow Channel

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Abstract— **Performance of Proton Exchange Membrane Fuel Cell (PEMFC) is greatly influenced by design and operating parameters. Water generation on cathode side affects the PEMFC performance. So in this analysis different operating parameters are taken to overcome this kind of problems. In this numerical analysis high temperature Proton Exchange Membrane Fuel Cell with single flow channel configuration is selected to investigate the effect of Anode Hydrogen concentration under four different operating temperatures (463K, 473K, 483K, and 493K) by using COMSOL Multiphysics software. Result shows that the Proton Exchange Membrane Fuel Cell at an operating temperature of 463K gives the better Anode Hydrogen concentration among the other three operating temperatures.**

Index Terms— **High temperature PEMFC, single flow channel, Anode Hydrogen concentration, COMSOL.**

1. Introduction

As the number of fossil fuel based power generator systems has increased in various applications, the necessity for a viable alternative has captured worldwide attention. The automakers and industrial developers are investigating many possible solutions in order to increase engines efficiency and to reduce environmental polluting fumes emanated from the engine exhaust for both stationary and transportation applications. Proton exchange membrane fuel cells (PEMFCs) have recently approved on the scene and are expected to play a significant role in the next generation of energy consumption systems as a clean power source for various applications. These cells work by direct conversion of chemical energy of reaction between hydrogen and oxygen into electricity. In addition, there is several coupled fluid flow and mass transport processes that occur in a fuel cell in conjunction with the electrochemical reaction. The main advantages of PEMFCs are low operating temperature, high-energy efficiency and low environmental pollution [1]. The water management is currently considered as one of the crucial issues to be fully understood and optimized before a successful commercialization of PEM fuel cells, since sufficient amount of water is necessary for maintaining the membrane ion conductivity whereas excess water, or water flooding, may block the porous electrodes and flow channels, reducing the reactant mass transfer to catalytic sites [2–5]. Due to the growing concerns on the depletion of petroleum based energy resources and climate change; fuel cell technologies have received much attention in recent years owing to their high efficiencies and low emissions. Fuel cells, which are classified according to the electrolyte employed, are electrochemical devices that directly convert chemical energy stored in fuels such as hydrogen to electrical energy. Its efficiency can reach as high as 60% in electrical energy conversion and overall 80% in co-generation of electrical and thermal energies with >90% reduction in major pollutants [6]. Ionic and water transport in membranes plays an important role in fuel cell operation. The ionic transport resistance directly determines the Ohmic loss of cell voltage and associated Joules heating. Formation of local hot spots may occur at high resistance sites, leading to membrane pin-hole formation and other degradation issues. A sufficient hydration level of membranes is critical to their ionic conductivity. It has also been observed that dryness of membranes may cause cracks and degradation issues. [7, 8]. Membrane water content between the membrane with liquid water and with saturated water vapor at equilibrium [9]. Both of the surrounding waters exhibit unity water activity. This phenomenon, generally referred to as Schroeder's paradox", is observed in a wide variety of polymer materials and solvents [10 – 12].

2. Problem Formulation

Based on the above literatures we have observed that the water generation and water accumulation is the major issue in PEMFC performance. Effective concentration of Hydrogen gases on anode side gives the better performance improvement of PEM fuel cell. So in this study numerical analysis has been taken in high temperature PEMFC to evaluate the effect of Anode Hydrogen concentration for different operating temperatures.

3. Modeling

Modeling of high temperature PEMFC with single flow channel is done by using SOLID WORKD modeling package with the following different design parameters such as cell length, channel height, channel width, rib width, GDL width, porous electrode thickness and membrane thickness are taken into account to carry out the complete design of the single flow channel PEM fuel cell model. Table.1 shows the different dimensions of the isometric model of PEM fuel cell.

Table 1 Design parameters

Sl.No.	Description	Notation	Value	Units
1.	Cell length	L	0.02	meters
2.	Channel height	H_{ch}	1×10^{-3}	
3.	Channel width	W_{ch}	1×10^{-3}	
4.	Rib width	W_{rib}	1×10^{-3}	
5.	GDL width	H_{gdl}	380×10^{-6}	
6.	Porous electrode thickness	$H_{electrode}$	50×10^{-6}	
7.	Membrane thickness	$H_{membrane}$	100×10^{-6}	

Based on the above different design parameters three dimensional model of high temperature PEM fuel cell with single flow channel configuration is successfully designed by using SOLID WORKS software. Three dimensional model of PEM fuel cell is shown if the Fig.1.

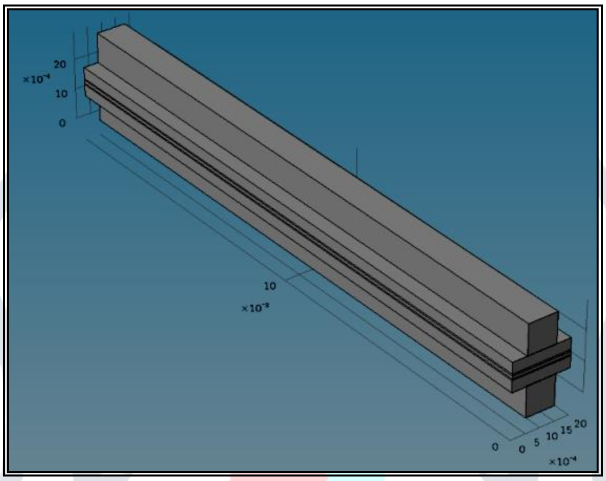

Figure 1 Isometric model of single flow channel PEMFC

4. Meshing

Three dimensional model of the single flow channel PEMFC is imported into COMSOL Multiphysics software to mesh the entire model. Meshing is done by using mesh domain with fine mesh element to get the most accurate results. Complete mesh model is shown in Fig.2.

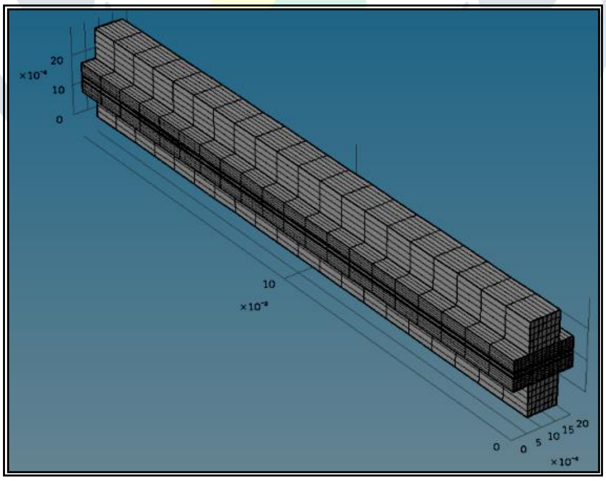

Figure 2 Mesh model of single flow channel PEMFC

5. Analysis

COMSOL Multiphysics software is used to carry out a numerical analysis of high temperature PEM fuel cell with single flow channel configuration. The following different operating parameters like as gas diffusion layer porosity, gas diffusion layer permeability, gad diffusion layer electrical conductivity, inlet H_2 mass fraction, inlet H_2O mass fraction and inlet oxygen mass fraction etc., are taken into account to carry out the analysis. Inlet and outlet paths are clearly defined in boundary conditions domain.

6. Results and Discussions

The following results has been obtained for the numerical analysis of High temperature PEM fuel cell with single flow channel configuration under the four different operating temperatures to investigate the effect of Anode Hydrogen concentration with respect to the four different operating temperatures.

6.1 Effect of Anode Hydrogen concentrations at 463K

Concentration of Hydrogen in Anode side at an operating temperature of 463K is shown in Fig.3. It shows that the Hydrogen concentration is maximum at inlet of the flow channel then it is gradually decreased towards the outlet of the flow channel. Maximum and minimum concentration of Hydrogen in Anode side obtained in this case is 12.504 mol/m^3 & 11.943 mol/m^3 respectively.

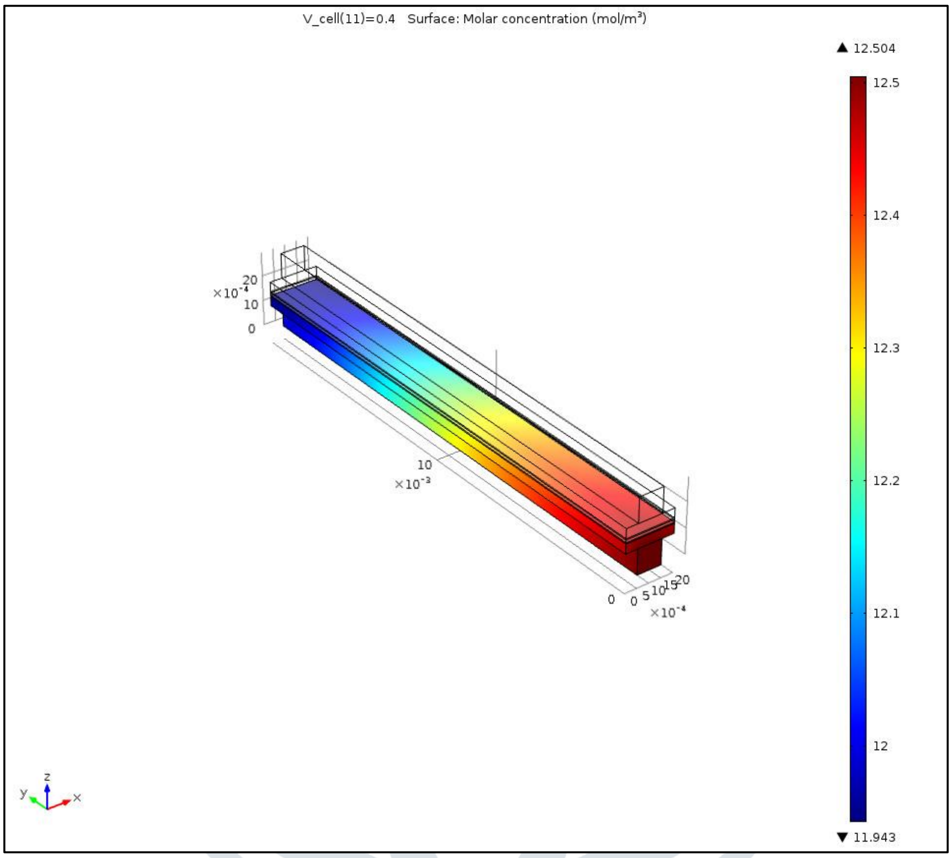

Figure 3 Effect of Anode Hydrogen concentrations at 463K

6.2 Effect of Anode Hydrogen concentrations at 473K

Hydrogen concentration in Anode side at an operating temperature of 473K is shown in Fig.4. It shows that the Hydrogen concentration is maximum at inlet of the flow channel then it is gradually decreased towards the outlet of the flow channel. Maximum and minimum concentration of Hydrogen in Anode side obtained in this case is 12.240 mol/m^3 & 11.674 mol/m^3 respectively.

6.3 Effect of Anode Hydrogen concentrations at 483K

Anode Hydrogen concentration at an operating temperature of 483K is shown in Fig.5. It shows that the Hydrogen concentration is maximum at inlet of the flow channel then it is gradually decreased towards the outlet of the flow channel. Maximum and minimum concentration of Hydrogen in Anode side obtained in this case is 11.986 mol/m^3 & 11.416 mol/m^3 respectively.

6.4 Effect of Anode Hydrogen concentrations at 493K

Effect of concentration of Hydrogen in cathode side at an operating temperature of 493K is shown in Fig.6. It shows that the Hydrogen concentration is maximum at inlet of the flow channel then it is gradually decreased towards the outlet of the flow channel. Maximum and minimum concentration of Hydrogen in Anode side obtained in this case is 11.743 mol/m^3 & 11.168 mol/m^3 respectively.

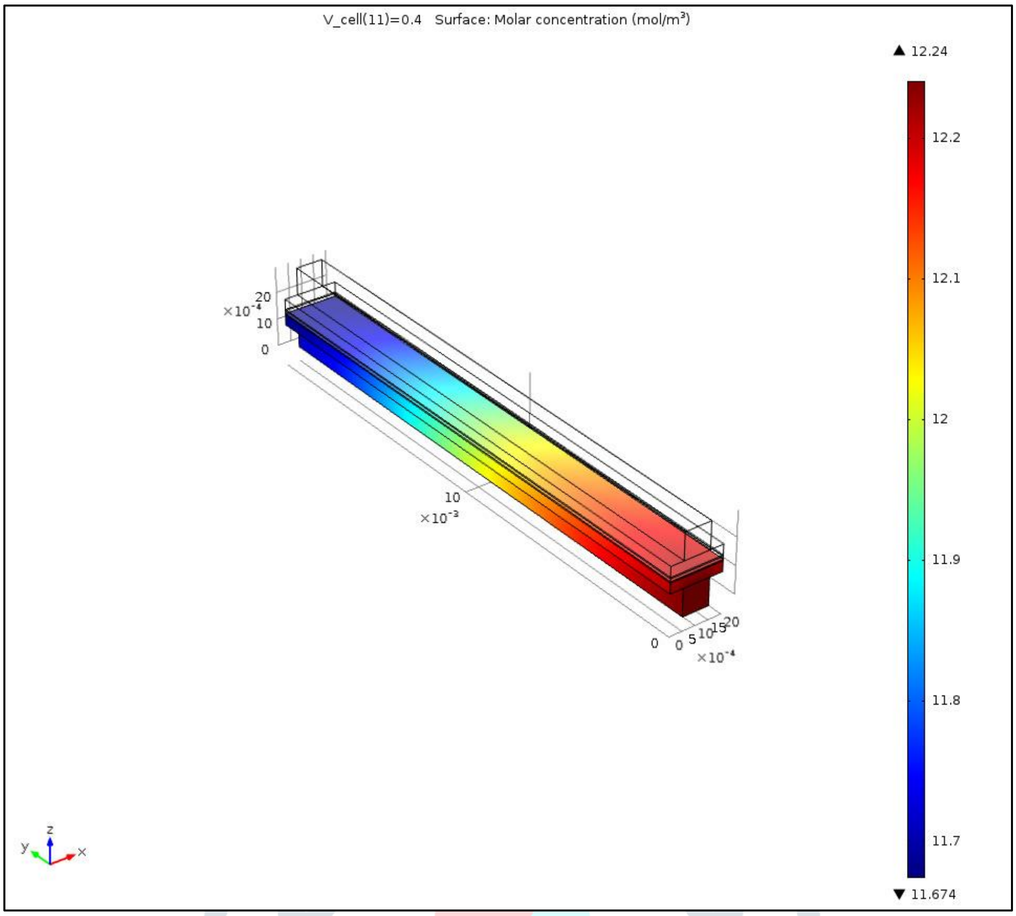

Figure 4 Effect of Anode Hydrogen concentrations at 473K

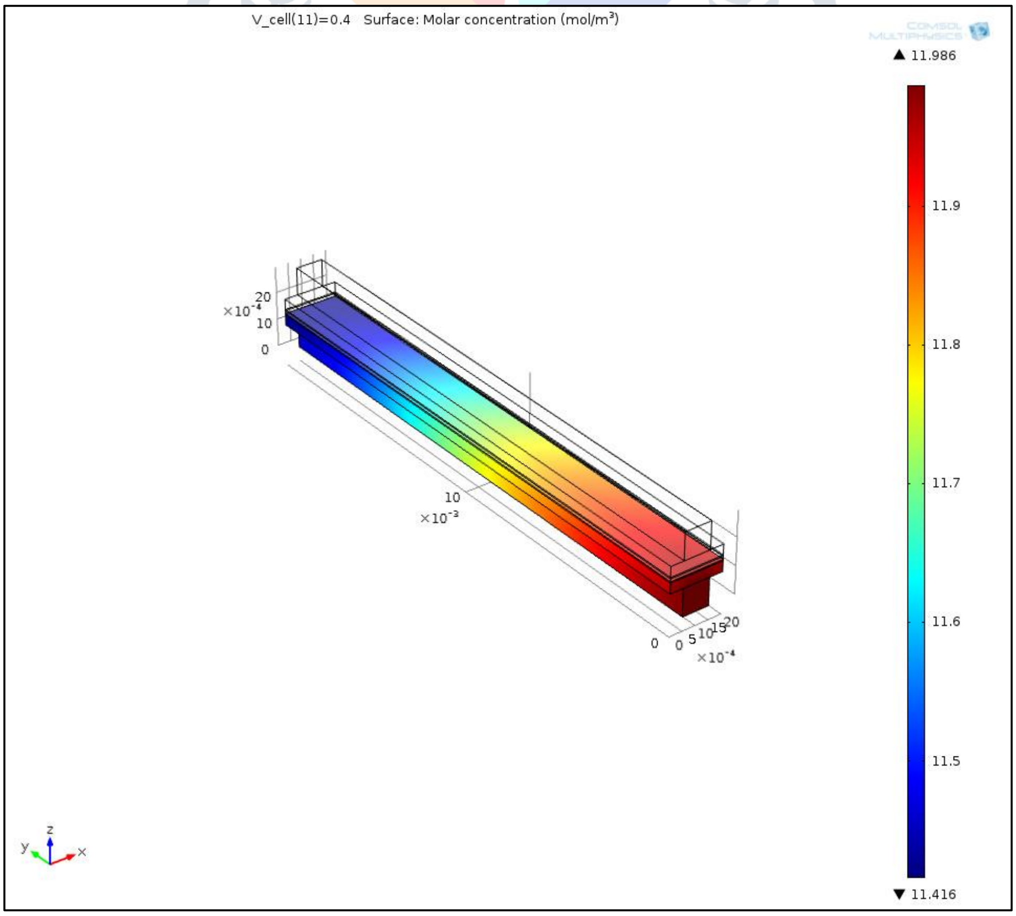

Figure 5 Effect of Anode Hydrogen concentrations at 483K

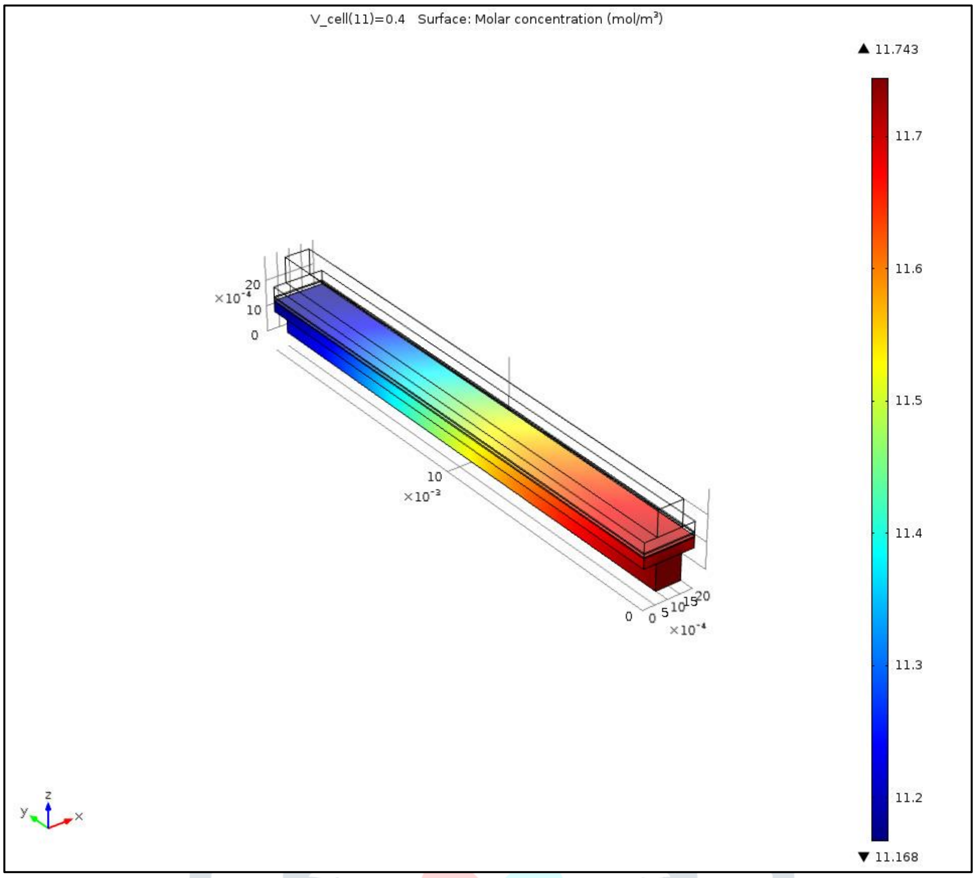

Figure 6 Effect of Anode Hydrogen concentrations at 493K

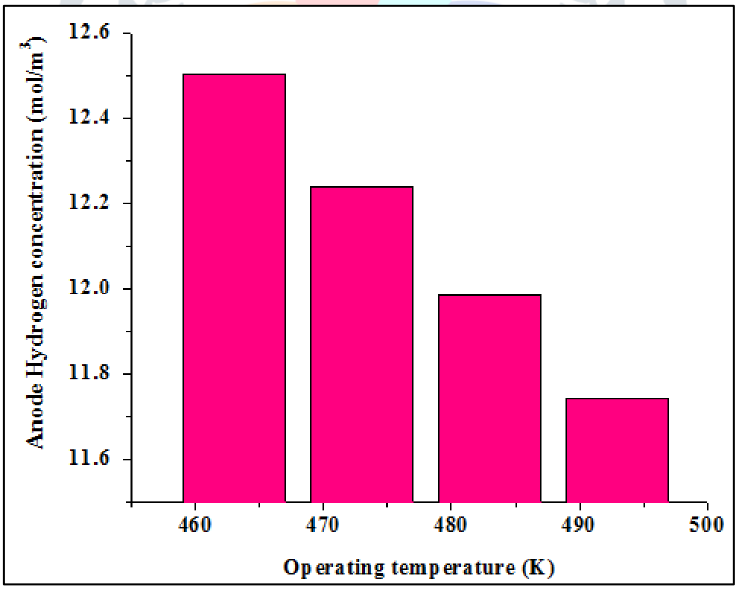

Figure 7 Anode Hydrogen concentrations at different operating temperatures

Effect of Anode Hydrogen concentrations for four different operating temperatures is shown in the Fig.7. It clearly shows that the Concentration of Hydrogen in Anode side is maximum at an operating temperature of 463 K then it is gradually decreased with respect to the other three operating temperatures.

7. SUMMARY

Numerical analysis of high temperature PEM fuel cell with single flow channel configuration is successfully carried out to investigate the effect of Anode Hydrogen concentrations by using COMSOL Multiphysics software under the different operating temperatures. The following conclusions have been made based on the numerical results which were obtained from the COMSOL Multiphysics software. High temperature PEM fuel cell with an operating temperature of 463K gives the better Anode Hydrogen concentrations (12.504 mol/m^3) compared with other three operating temperatures. Thus the results clearly show that the effective distribution of Hydrogen concentration on Anode side is maximum at the lower operating temperatures.

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