Effect of Reactant Gases Velocity Distribution in Single Flow Channel High Temperature PEM Fuel Cell

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***Abstract*— Proton Exchange Membrane Fuel Cell (PEMFC) performance is decided by means of various design and operating parameters. Creation of water droplet on cathode side is reducing the penetration of hydrogen and oxygen gas in between the gas diffusion layer. So effective distribution of hydrogen and oxygen gases are resulting the reduced level of water droplet generation. In this study high temperature Proton Exchange Membrane Fuel Cell with single flow channel configuration is selected to investigate the effect of reactant gases velocity distribution at gas diffusion layer under the 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 493K gives the better reactant gases velocity distribution at gas diffusion layer among the other operating temperatures.**

Keywords—High temperature PEMFC, single flow channel, GDL, reactant gases velocity distribution, COMSOL.

I. INTRODUCTION

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 [1]. The Proton Exchange Membrane (PEM) fuel cell has been regarded as an ideal power source for a variety of applications due to its significant advantages, i.e., high efficiency, low emission, silence and simplicity [2]. The PEMFCs are currently under rapid development and promise to become an economically viable commercial power source in many areas, especially for transportation, stationary, portable and automobile applications, because of their high energy density at low operating temperatures and zero emissions [3]. Numerical investigation has been carried out in parallel channel flows and developed a strategy for a small variation (2%) of flow velocity among channels [4]. Numerical investigation on the flow distribution in a stack has been conducted, and concluded that the channel resistance, manifold dimension and gas feed rate may affect flow distributions [5]. Gas flow channels (GFCs) are important components of PEM fuel cell and they supply and distribute hydrogen fuel and oxygen reactant for reactions and remove byproduct water. Insufficient supply of reactants will lead to hydrogen/oxygen starvation, reducing cell performance and durability [6]. Flow distribution model has been modeled to examine the sensitivity of stack performance to operating conditions (inlet velocity and pressure) and design parameters (manifold, flow configuration and friction factor [7]. The flow field layout mainly affects the reactant and water distribution inside the cell. There were studies numerically and experimentally [8-10]. At saturation temperature of 90˚C and 95˚C larger amount of water is provided into cell by the increasing of the humidity of the reactant streams. Operating fuel cell below the dew point of the reactant gas streams means that the water from the reactant stream partially condensed when it enters the cell. The excessive liquid water from reactant gases then partially blocks the pore network of anode/cathode and GDLs. Thus, in the higher current region,

water leads to poor cell performance. Water blocking affects the cell performance, although this effect was limited in the medium current region [11].

II. PROBLEM FORMULATION

Based on the above literature study performance of the PEM Fuel Cell is mostly affected by the generation and accumulation of water content in cathode side of the cell. Flow channels and the operating parameters are the key parameters which are to be concentrated to improve the PEM fuel cell's performance. So in this analysis numerical analysis has been carried in high temperature PEM fuel cell with single flow channel to overcome this type of issues inside the PEM fuel cell.

III. MODELING

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 DIMENSIONS OF SINGLE FLOW CHANNEL PEM FUEL CELL

Sl.No.	Description	Value	Units
1.	Cell length	0.02	m
2.	Channel height	1×10^{-3}	
3.	Channel width	1×10^{-3}	
4.	Rib width	1×10^{-3}	
5.	GDL width	380×10^{-6}	
6.	Porous electrode thickness	50×10^{-6}	
7.	Membrane thickness	100×10^{-6}	

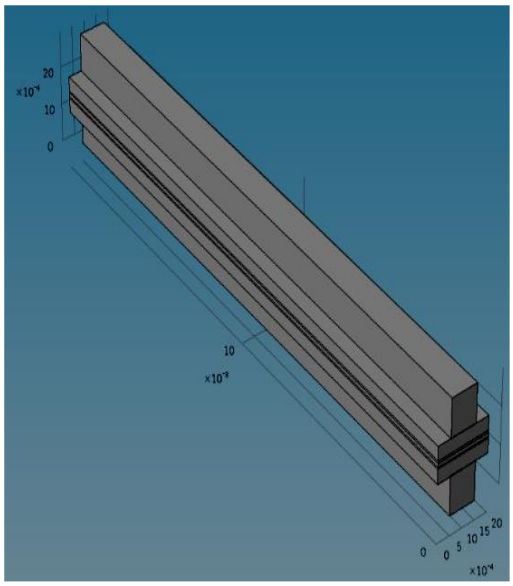

Fig. 1. Isometric model high temperature single flow channel PEMFC

IV. MESHING

After the successful completion of the three dimensional model of single flow channel PEM fuel cell model, COMSOL Multiphysics software is used to mesh the entire geometry model to get the accurate numerical results. Fine mesh elements are chosen to discretize the entire isometric model. Complete mesh model is shown in Fig.2.

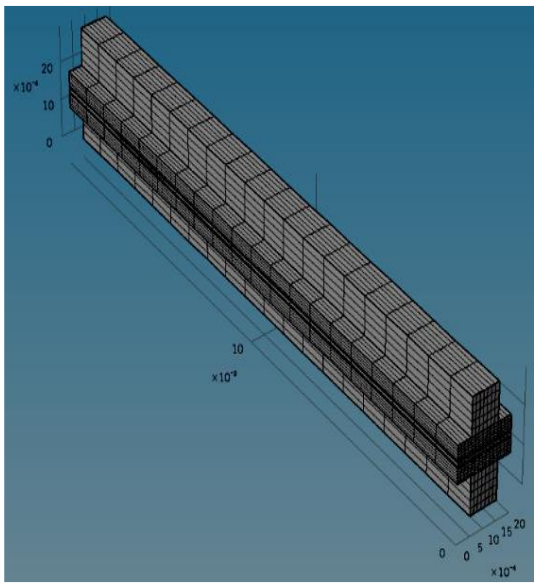

Fig.2. Single flow channel high temperature PEMFC Mesh model

V. ANALYSIS

Numerical analysis of high temperature PEM fuel cell with single flow channel configuration has been carried out by using COMSOL Multiphysics software. Different operating and boundary conditions are defined to carry out the complete numerical analysis. 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 for this numerical analysis. Inlet and outlet paths are clearly defined in boundary conditions domain.

VI. RESULTS AND DISCUSSIONS

A. Effect of reactant gases velocity distribution in GDL at 463K

Reactant gases velocity distribution in gas diffusion layer at an operating temperature of 463K is shown in Fig.3. It shows clearly the initial velocity distribution is zero at starting of the channel inlet then the velocity is increased at the middle portion of the gas diffusion layer. Maximum and minimum gas diffusion layer velocity obtained in this case is 0 & 1.1756 m/s respectively.

B. *Effect of reactant gases velocity distribution in GDL at 473K*

Effect of reactant gases velocity distribution in gas diffusion layer at an operating temperature of 473K is shown in Fig.4. Distribution of Oxygen and Hydrogen velocity is minimum at the end of the gas diffusion layer and it is maximum at the middle portion of the gas diffusion layer. Compared with the previous case velocity distribution is slightly increased due to the increased operating temperature. Maximum and minimum gas diffusion layer velocity obtained in this case is 0 & 1.1776 m/s respectively.

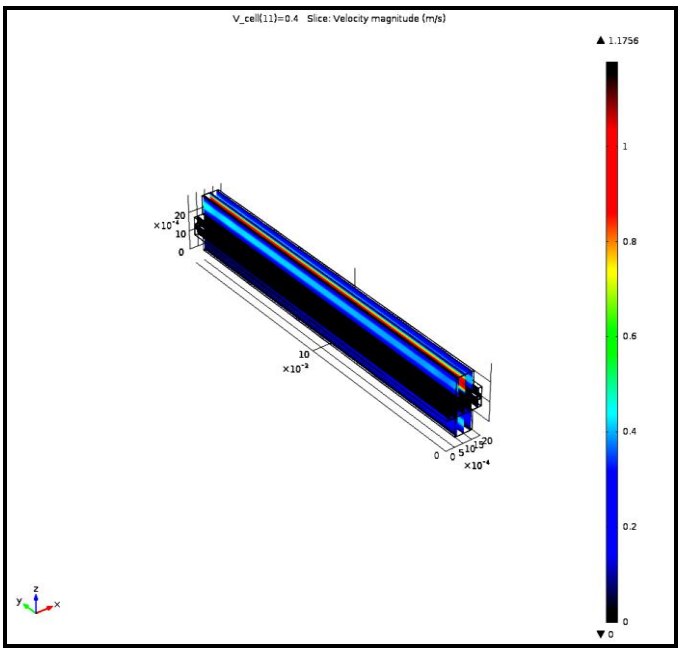

Fig.3. Reactant gases velocity distribution in GDL at 463K

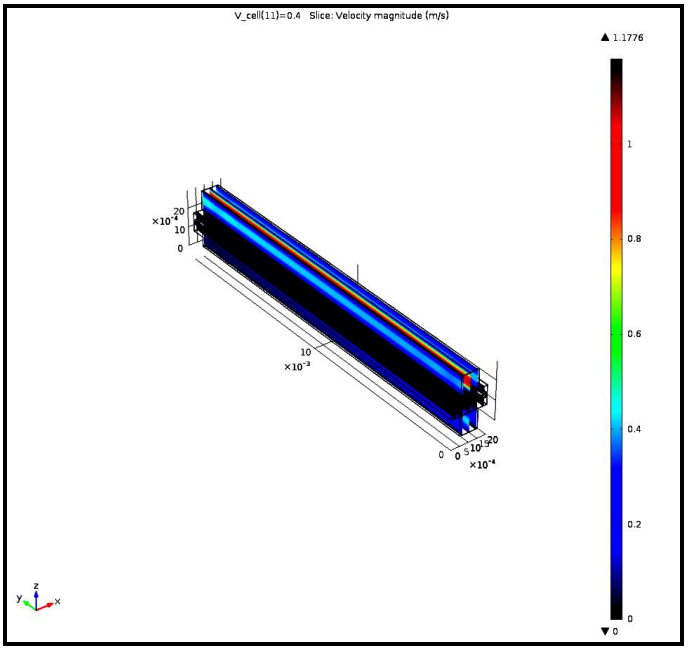

Fig.4. Reactant gases velocity distribution in GDL at 473K

C. *Effect of reactant gases velocity distribution in GDL at 483K*

Effect of velocity distributions of the reactant gases at gas distribution layer with an operating temperature of 483K are shown in Fig.5. It shows that the reactant gases velocity is zero at the starting stage and it gets a maximum magnitude at the middle portion of gas distribution layer. Maximum and minimum velocity distribution of reactant gases at gas diffusion layer is 0 & 1.1776 m/s respectively.

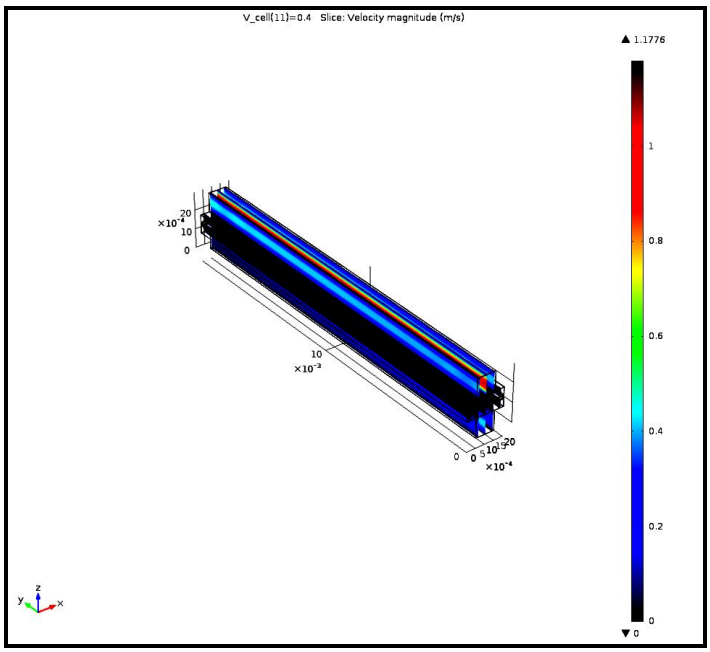

Fig.5. Reactant gases velocity distribution in GDL at 483K

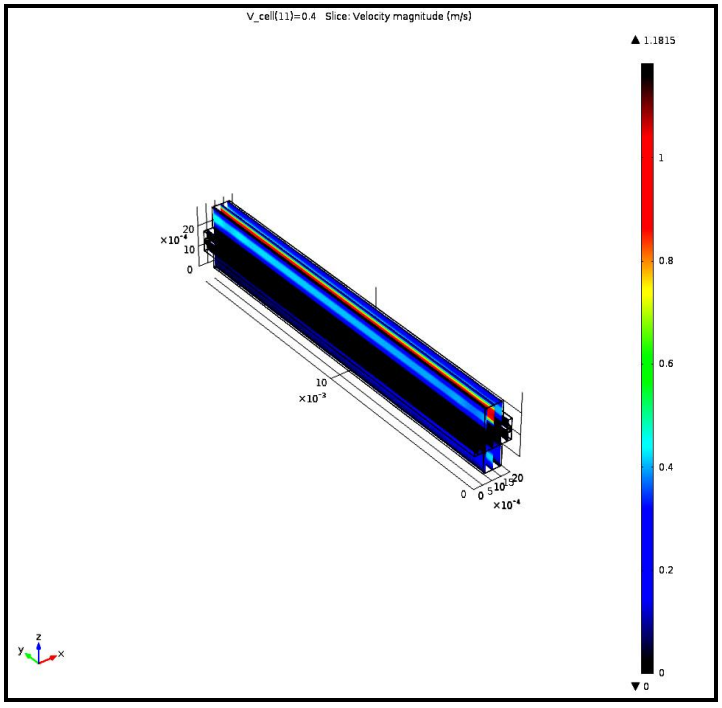

Fig.6. Reactant gases velocity distribution in GDL at 493K

D. *Effect of reactant gases velocity distribution in GDL at 493K*

Effect of velocity distributions of the reactant gases at gas distribution layer with an operating temperature of 493K are shown in Fig.6. It shows that the reactant gases velocity is zero at the starting stage and it gets a maximum magnitude at the middle portion of gas distribution layer. Maximum and minimum velocity distribution of reactant gases at gas diffusion layer is 0 & 1.1815 m/s respectively.

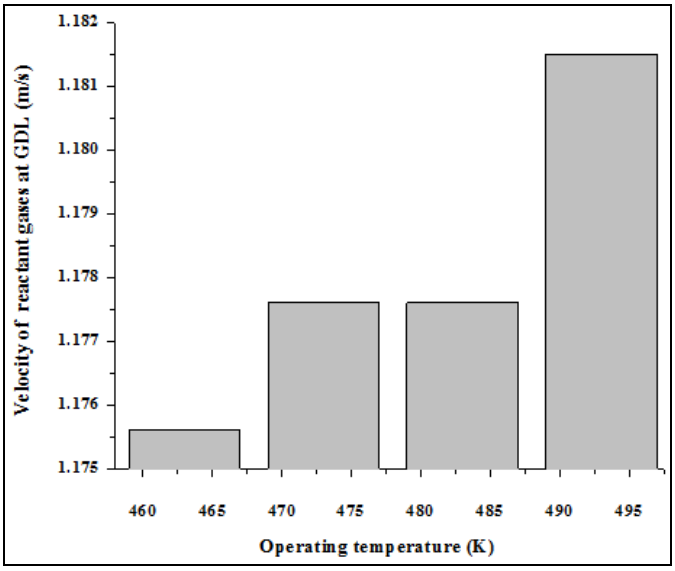

Fig.7. Effect of reactant gases velocity distribution at various operating temperatures

VII. SUMMARY

Numerical analysis of high temperature PEM fuel cell with single flow channel configuration is successfully carried out investigates the effect of reactant gases velocity distributions at gas diffusion layer 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 493K gives the better reactant gases velocity distribution (1.1815 m/s) at gas diffusion layer compared with other four operating temperatures. Thus the result clearly shows that the effective velocity distribution of reactant gases is drastically increased with the increasing operating temperatures.

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