EFFECTS OF GAS DIFFUSION LAYER PRESSURE FOR VARIOUS CELL VOLTAGES IN A SERPENTINE FLOW FIELD PROTON EXCHANGE MEMBRANE FUEL CELL

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ABSTRACT

A three-dimensional computational fluid dynamics model of a PEM fuel cell with 25×25 cm^2reactive area serpentine flow field model is presented in this paper. A numerical investigation is carried out to evaluate the effects of gas diffusion layer (GDL) pressure for various cell voltages in a 25×25 cm^2 reactive area serpentine flow field PEM fuel cell. Numerical predictions show that the GDL pressure for Serpentine Flow Field PEM fuel cell design can be enhanced by increasing the cell voltage and the best overall GDL pressure occurs for a cell voltage of 0.9V. The results also show that the GDL pressure is significantly increases with respect to the increasing cell voltages on serpentine flow field design PEMFC.

Keyword: - *PEM fuel cell; serpentine flow field; GDL pressure; cell voltages; CFD.*

1. INTRODUCTION

The polymer electrolyte membrane (PEM) fuel cell is a promising candidate as zero-emission power source for transport and stationary cogeneration applications due to its high efficiency, low-temperature operation, high power density, fast start-up, and system robustness [1]. Water is the main product of the electrochemical reaction in a proton exchange membrane (PEM) fuel cell. Where the water is produced over the active area of the cell and how it accumulates within the flow fields and gas diffusion layers, strongly affects the performance of the device and influences operational considerations such as freeze and durability [2]. A serpentine flow channel is one of the most common and practical channel layouts for a polymer electrolyte membrane (PEM) fuel cell since it ensures the removal of water produced in a cell with acceptable parasitic load. During the reactant flows along the flow channel, it can also leak or cross to neighboring channel via the porous gas diffusion layer due to the high pressure gradient caused by the short distance [3]. Gas diffusion layer (GDL) is one of the critical components acting both as the functional as well as the support structure for membrane–electrode assembly in the proton exchange membrane fuel cell (PEMFC). The role of the GDL is very significant in the H2/air PEM fuel cell to make it commercially viable [4]. The relative influence of convection depends highly on in-plane permeability of the gas diffusion layer and channel length, and is relatively independent of gas diffusion layer thickness. By designing fuel cells to utilize enhanced in-plane convection, it is suggested that losses associated with low oxygen content as well as liquid water buildup in the catalyst layer can be reduced [5]. The coupling of the local activation over potential distribution and reactant concentration makes it possible to predict the local current density distribution more accurately [6]. The air stoichiometric flow rate also influenced the performance of the fuel cell directly by supplying oxygen and indirectly by influencing the humidity of the membrane and water flooding in cathode side [7].

2. MODELING & ANALYSIS

The commercial available COMSOL Multiphysics software is used to create and analyze the complete three dimensional model of serpentine floe field PEM fuel cell. The complete three dimensional model is shown in figure.1(A). A fuel cell with 25×25 cm^2 reactive area serpentine flow field model square cross-section was considered. In general the PEM fuel cell was consisting of seven layers like membrane, anode and cathode catalyst layers, anode and cathode Gas Diffusion Layers (GDL), anode and cathode flow channels. The entire three dimensional model generation is taking place with the "PEMFC adding domains" in the COMSOL software. By using "forward-looking description domains", the required modeling terms were produced with respect to the relevant geometry parameters (Thickness, Length, height, width, etc.).

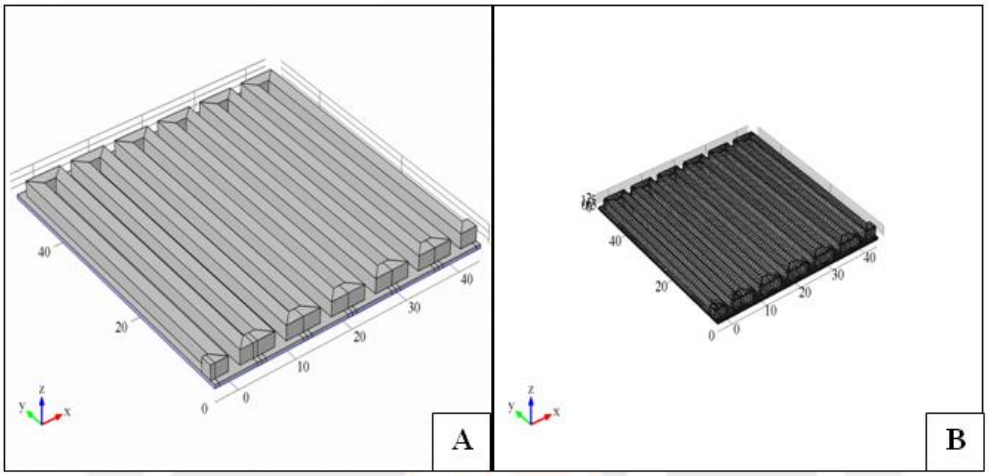

Fig-1: Serpentine flow field PEMFC (A) 3D model (B) Mesh model

The Cartesian coordinates were used to refer to the whole geometry in the necessary coordinate location. Finally the complete three dimensional model of serpentine flow field PEMFC had been created by reclaiming the data from modeling terms table in the software. Next the different operating parameters like Lumped anode resistance, membrane resistance, Cell temperature, Oxygen reference concentration, GDL Porosity, GDL permeability, membrane conductivity, GDL electric conductivity, Hydrogen molar mass, water molar mass, Oxygen molar mass, inlet mass fraction of H_2, inlet mass fraction of O_2 and inlet mass fraction of H_2O, inlet velocity, fluid viscosity, Nitrogen molar mass, water molar mass, Oxygen molar mass, N_2-H_2O binary diffusion coefficient, O_2-N_2 binary diffusion coefficient, O_2-H_2O binary diffusion coefficient, reference pressure and cathodic transfer coefficient were taken into account for the complete numerical analysis on serpentine flow field PEMFC under six cell potentials. The PEMFCs were functioned at a temperature of 50°C and an operating pressure of 1.5 bar respectively.

3. RESULTS AND DISCUSSIONS

The complete three dimensional serpentine flow field PEM fuel cell with various modeling components like membrane, anode and cathode catalyst layers, anode and cathode GDL, anode and cathode flow channels was operated at the similar operating conditions of 60°C temperature and 2.0 bar pressure. In the beginning the serpentine flow field PEMFC with a cell voltage of 0.4V was engaged and analyzed at the above mentioned operating parameters to evaluate the GDL pressure distribution. The GDL pressure distribution of 14.538 Pa was obtained corresponding to the cell potential of 0.4 V at a temperature 60°C. Next serpentine flow field PEMFC with a cell voltage of 0.5V was involved and analyzed at the above mentioned operating parameters to evaluate the GDL pressure distribution. The GDL pressure distribution of 14.702 Pa was obtained corresponding to the cell potential of 0.5V at a temperature 60°C. Next serpentine flow field PEMFC with a cell voltage of 0.6V was involved and analyzed at the above mentioned operating parameters to evaluate the GDL pressure distribution. The GDL pressure distribution of 14.781Pa was obtained corresponding to the cell potential of 0.6V at a temperature 60°C. Next serpentine flow field PEMFC with a cell voltage of 0.7V was involved and analyzed at the above mentioned operating parameters to evaluate the GDL pressure distribution. The GDL pressure distribution of 14.705 Pa was obtained corresponding to the cell potential of 0.7V at a temperature 60°C.Next serpentine flow field PEMFC with a cell voltage of 0.8V was involved and analyzed at the above mentioned operating parameters to evaluate the GDL pressure distribution. The GDL pressure distribution of 14.705 Pa was obtained corresponding to the cell potential of 0.8V at a temperature 60°C. Next serpentine flow field PEMFC with a cell voltage of 0.9V was involved and analyzed at the above mentioned operating parameters to evaluate the GDL pressure distribution. The GDL pressure distribution of 14.789 Pa was obtained corresponding to the cell potential of 0.9V at a temperature 60°C.The effect of Gas Diffusion Layer (GDL) pressure distribution inside the serpentine flow field PEMFC for all cell voltages were illustrated in Fig.4in which the cell voltage values (V) were taken in x-axis and the Gas Diffusion Layer (GDL) pressure distribution (P) were taken in y-axis.

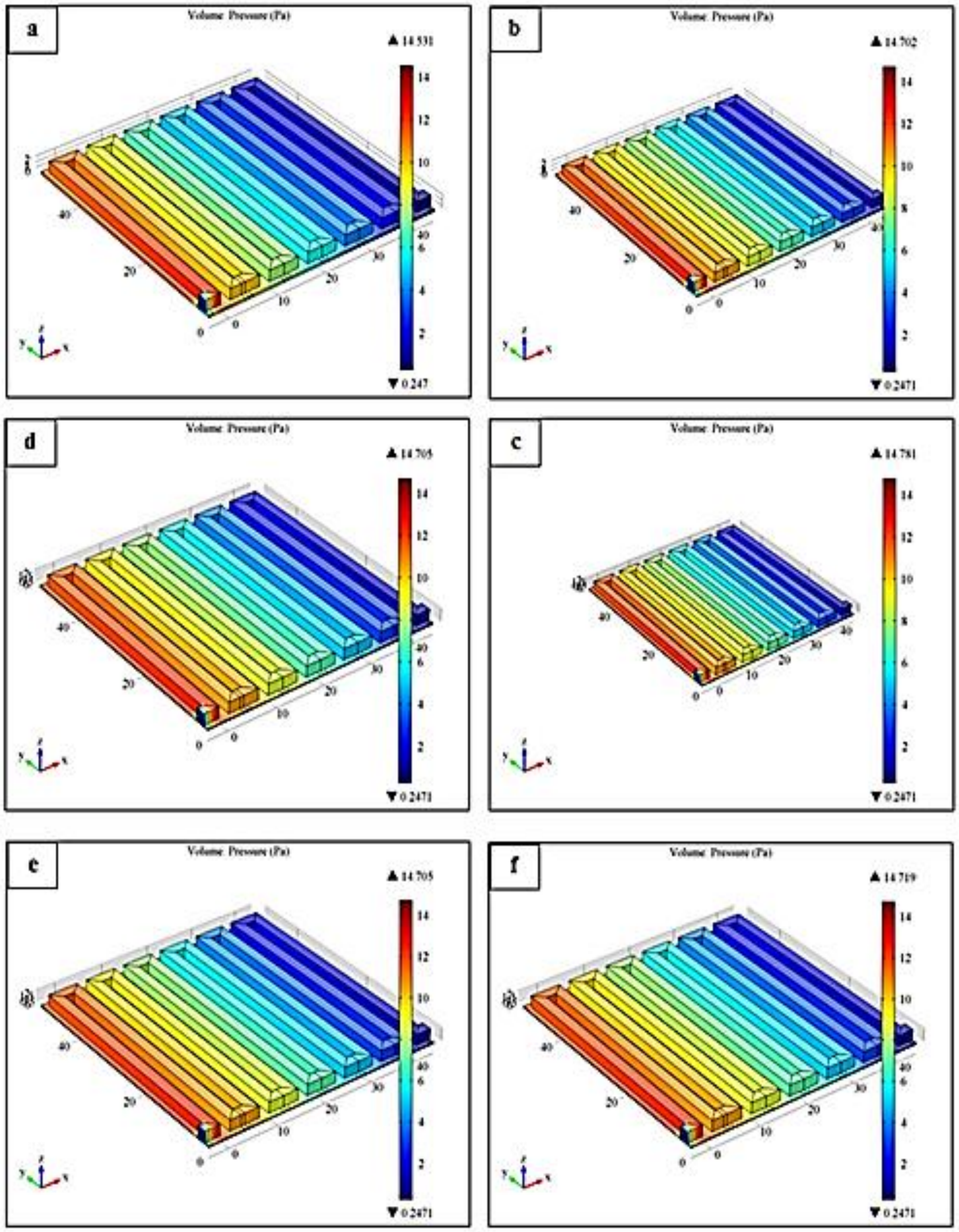

Fig-2: GDL pressure distribution at cell potential (a) 0.4V (b) 0.5V (c) 0.6V (d) 0.7V (e) 0.8V (f) 0.9V

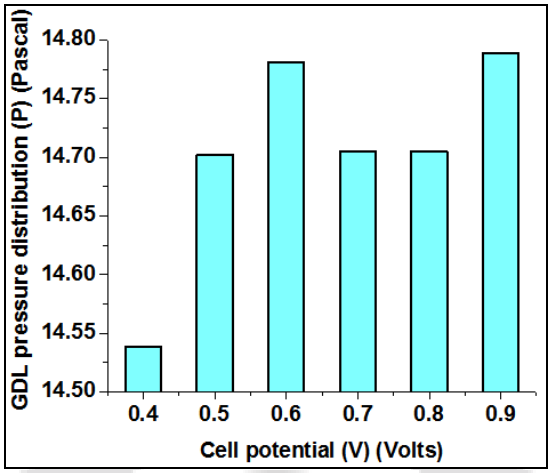

Fig -3: GDL pressure distributions for all cell voltages

4. SUMMARY

The entire three dimensional 25×25 cm^2 reactive areas serpentine flow field proton exchange membrane fuel cell is numerically analyzed using commercial existing software package to evaluate the effect of gas diffusion layer pressure distribution under six different cell voltages. The six different cell voltages and gas diffusion layer pressures were considered for this analysis. Apart from the cell voltages and GDL pressure, all other modeling and operational parameters were retained same for all the analysis. From this numerical analysis it can be concluded that the serpentine flow field PEMFC with an operational voltage of 0.9V has created the higher GDL pressure distribution of 14.789 Pa compared to other five cell voltages. Due to the increasing operational cell voltages inside the cell, the GDL pressure distribution of the PEMFC at 0.9V is better than other cell voltages.

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