

Effect of Cell Potentials on Gas Diffusion Layer Velocity with Serpentine Flow Channel in PEM Fuel Cell

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ABSTRACT

In this work, the influences of various cell voltages on the reactant gases velocity distribution at Gas Diffusion Layer (GDL) with conventional serpentine flow field in Proton Exchange Membrane Fuel Cell (PEMFC) is numerically studied. The six different cell potentials like (0.4, 0.5, 0.6, 0.7, 0.8 and 0.9V) were taken into account to optimize an effective velocity distribution of the reactant gases inside the cell at Gas Diffusion Layer. The numerical results show that the reactant gases distribution at GDL is enhanced with increases in cell potentials. Under the optimal fuel flow rate conditions, the PEM fuel cell with a cell potential of 0.6V provides the better velocity distribution of reactant gases at the Gas Diffusion Layer among the other five cell potentials.

Keywords: PEM Fuel Cell; Serpentine flow fields; GDL velocity; Cell voltages, COMSOL.

I. INTRODUCTION

Efforts in developing various models for PEM fuel cells have been increasing in recent years, and thus creating an urgent need for systematic experimental data on fuel cells with commercially available components [1]. The proton Exchange membrane fuel cell (PEMFC) performance depends not only on many factors including the operation conditions, transport phenomena inside the cell and kinetics of the electrochemical reactions, but also in its physical components; membrane electrode assembling (MEA) and bipolar plates (BPs) [2]. The PEM fuel cell performance is enhanced with increases in cathode inlet gas flow rate, cathode humidification temperature and cell temperature. However, as cell temperature is higher than or equal to anode humidification temperature, the cell performance is deteriorated due to failure in humidification of the cell [3]. Proper water management in polymer electrolyte membrane (PEM) fuel cells is critical to achieve the potential of PEM fuel cells. Membrane electrolyte requires full hydration in order to function as proton

conductor, often achieved by fully humidifying the anode and cathode reactant gas streams [4]. Operating parameters that facilitated better water removal by evaporation like higher temperature and stoichiometric flow rates and lower inlet stream humidity resulted in higher net current [5]. The flow field design in bipolar plates is very important for improving reactant utilization and liquid water removal in proton exchange membrane fuel cells (PEMFCs) [6]. The serpentine flow field is the leading type of flow field used today in proton exchange membrane (PEM) fuel cells and for this reason optimization of serpentine flow field design is extremely important [7]. One of the most common types of flow field designs used in proton exchange membrane (PEM) fuel cells is the serpentine flow field. It is used for its simplicity of design, its effectiveness in distributing reactants and its water removal capabilities [8]. The failure in flow distribution among different unit cells may severely influence the fuel cell stack performance [9]. The gas diffusion layer (GDL) plays a very important role in the performance of Proton Exchange Membrane (PEM) fuel cells. The amount of compression on the GDL affects the contact resistance,

the GDL porosity, and the fraction of the pores occupied by liquid water, which, in turn, affect the performance of a PEM fuel cell [10].

II. METHODS AND MATERIAL

Modeling & Analysis

The marketable current COMSOL Multiphysics software is used to create and evaluate the complete model of serpentine flow field PEM fuel cell. The entire three dimensional model is shown in figure.1. A fuel cell with $25 \times 25 \text{ cm}^2$ 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.).

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, $\text{N}_2\text{-H}_2\text{O}$ binary diffusion coefficient, $\text{O}_2\text{-N}_2$ binary diffusion coefficient, $\text{O}_2\text{-H}_2\text{O}$ 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 1.0 bar respectively.

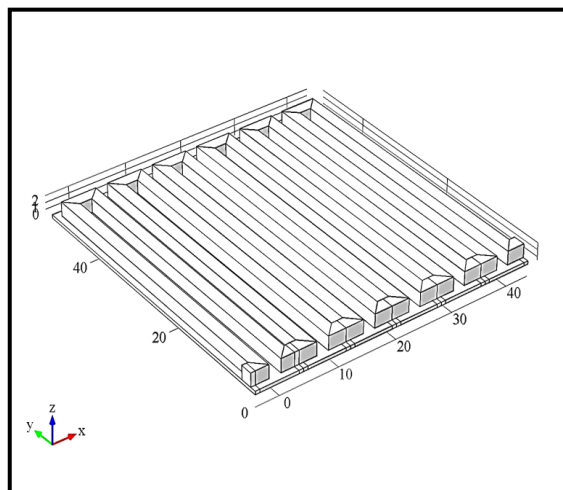


Figure 1: Serpentine Flow Field PEMFC Model

III. RESULT AND DISCUSSION

The overall three dimensional serpentine flow fields PEM fuel cell with several modeling modules 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 1.5 bar pressure.

In the start the serpentine flow field PEMFC with a cell voltage of 0.4V was involved and evaluated at the above mentioned operating parameters to estimate the reactant gases velocity distribution at Gas Diffusion Layer of the cell. The amount of GDL velocity distribution of the reactant gases 5.7302 m/s was obtained corresponding to the cell potential of 0.4 V at a temperature 50°C . Next the serpentine flow field PEMFC with a cell voltage of 0.5V was engaged and analyzed at the above mentioned operating parameters to evaluate the reactant gases velocity distribution at Gas Diffusion Layer of the cell. The amount of GDL velocity distribution of the reactant gases 5.9821m/s was obtained corresponding to the cell potential of 0.5 V at a temperature 50°C . Next the serpentine flow field PEMFC with a cell voltage of 0.6V was engaged and analyzed at the above mentioned operating parameters to evaluate the reactant gases velocity distribution at Gas Diffusion Layer of the cell. The amount of GDL velocity distribution of the reactant gases 9.0892 m/s was obtained corresponding to the cell potential of 0.6 V at a temperature 50°C . Next the serpentine flow field PEMFC with a cell voltage of 0.7V was engaged and analyzed at the above mentioned operating parameters to evaluate the reactant gases velocity distribution at Gas

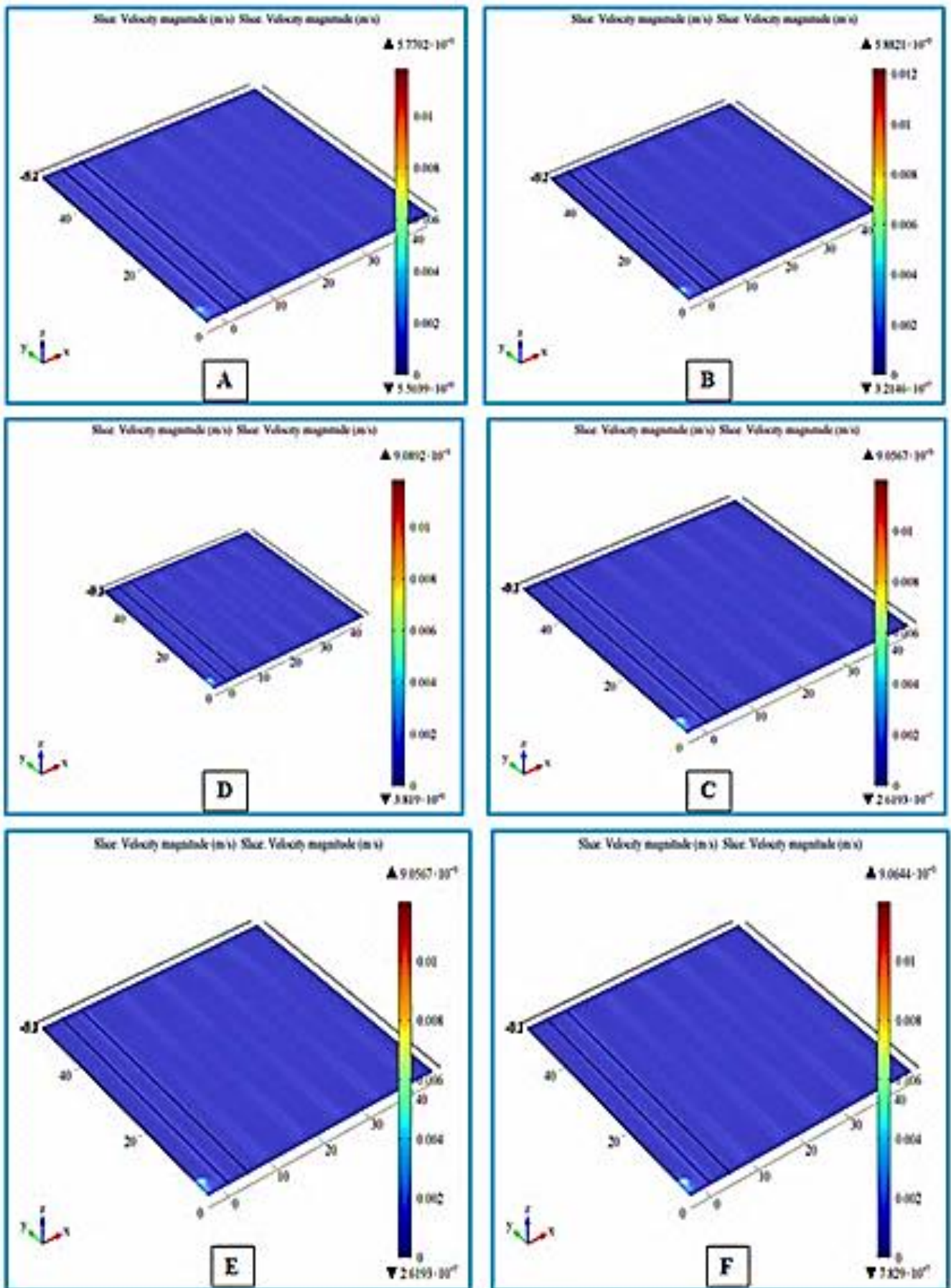


Figure 2: Gas Diffusion Layer velocity at cell potential (a) 0.4V (b) 0.5V (c) 0.6V (d) 0.7V (e) 0.8V (f) 0.9V

Diffusion Layer of the cell. The amount of GDL velocity distribution of the reactant gases 9.0567m/s was obtained corresponding to the cell potential of 0.7 V at a temperature 50°C . Next the serpentine flow field PEMFC with a cell voltage of 0.8V was engaged and analyzed at the above mentioned operating parameters to evaluate the reactant gases velocity distribution at Gas Diffusion Layer of the cell. The amount of GDL velocity distribution of the reactant gases 9.0567m/s was obtained corresponding to the cell potential of 0.8 V at a temperature 50°C . Next the serpentine flow field PEMFC with a cell voltage of 0.9V was engaged and analyzed at the above mentioned operating parameters to evaluate the reactant gases velocity distribution at Gas Diffusion Layer of the cell. The amount of GDL velocity distribution of the reactant gases 9.0664m/s was obtained corresponding to the cell potential of 0.9V at a temperature 50°C . The effect of GDL velocity distribution of the reactant gases in the serpentine flow field PEMFC for all cell potentials were illustrated in Fig.3 in which the different cell potentials (V) were taken in x-axis and the GDL velocity distribution were taken in y-axis.

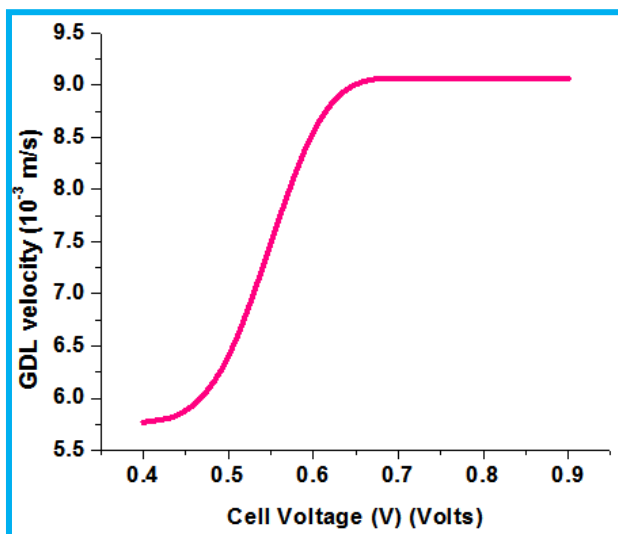


Figure 3: Gas Diffusion Layer velocity for all cell potentials

IV. CONCLUSIONS

A numerical analysis has been carried out on a Serpentine Flow Channel PEM Fuel Cell to investigate the adverse Effect of Cell Potentials on Gas Diffusion Layer Velocity and the results were summarized as follows. The highest gas diffusion layer velocity distribution of the reactant gases was found in the cell at

a cell potential of 0.6V . An effective distribution of reactant gases at gas diffusion layer had an adverse impact on the cell performance. The reactant gases velocity distribution at gas diffusion layer inside the cell leads to increases the current density of the entire PEM fuel cell. Therefore, the effective distribution of reactant gases at Gas Diffusion Layer is resulting in higher cell performance especially in the middle cell potentials. This work has demonstrated that velocity distribution of reactant gases inside the cells at middle cell potentials can be used to improve the serpentine flow field PEM fuel cell performance. It was also found that the velocity distribution of the reactant gases at Gas Diffusion Layer indeed improved the cell performances at average cell potentials without modified the operating and design parameters of the serpentine flow channel PEM Fuel cell.

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