Influence of Cell Potentials on theCathode Oxygen Concentration in a Serpentine Flow Field PEM Fuel Cell

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***Abstract*—The Proton Exchange membrane Fuel Cell (PEMFC) performance is influenced by not only on several factors as well as the operation conditions, transport phenomena inside the cell and kinetics of the electro chemical reactions. This work numerically investigated the adverse effect of an effective distribution of oxygen gases on cathode side for six different cell potentials in order to improve water management in a polymer electrolyte membrane fuel cell (PEMFC) with serpentine flow field design. The numerical results showed that higher cell potentials enhance the cell performance through the higher concentration of oxygen gages on cathode side compared than lower cell potentials.**

Keywords— Proton Exchange membrane Fuel Cell; Serpentine flow fields; Oxygen distribution; Cell potentials

I. INTRODUCTION

PEM fuel cells seem to be one of the most reliable ones. Some of the PEMFC advantages with regard to other types of fuel cells are their easy implementation and their longer lifetime. Furthermore, their low operation temperature, high power density, fast start-ups, soundness of the system and low emission have encouraged the interest of various industry sectors to open up new fields of application for these fuel cells, including the motor industry, the stationary power generation, portable applications, etc. [1].The effects of a poor or misdistribution of reactants in PEM stack flow fields is considered a crucial issue to be taken into account, as it leads to non-uniform current density, localized hot spots in the membrane, performance degradation, and material degradation [2].In general misdistribution in parallel channels may because, among others, by uneven flow resistances in the parallel channels caused by variations in channel dimensions, different flow lengths, uneven fouling, density and viscosity variations, and presence of two or more phases due to water content in the channels [3].Mainly, the cathode gas diffusion layer causes a decrease in performance of fuel cell when the process is mass transport limited. The liquid water formation from the electrochemical reaction results in water flooding of the porous media, especially the cathode gas diffusion layer, which obstructs the reactant gas that is flowing to the catalytic electrodes [4-6].An anode water removal was achieved by creating higher water concentration gradient between cathode and anode gas diffusion layer interfaces by applying the pressure drop between the inlet and outlet of the anode flow channels in order to increase the abilities of the water removal by the fuel stream due to the pressure gradient [7]. A serpentine channel configuration can provide an excellent cell performance, due to their ability to compensate the elimination of water at an acceptable pressure drop, as no liquid water content was observed in the cell by the neutron imaging technique [8]. So in this numerical study a three dimensional computational PEMFC with serpentine flow field design is selected to investigate the adverse effect on the cathode side Oxygen gas distribution under the six different cell potentials without changing the other design and operating parameters.

II. MODELING &ANALYSIS

The commercial existing COMSOL Multiphysics software is used to generate and analyze the complete model of serpentine floe field PEM fuel cell. The whole three dimensional model is shown in figure.1. 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.). 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 50ºC and an operating pressure of 1.0 bar respectively.

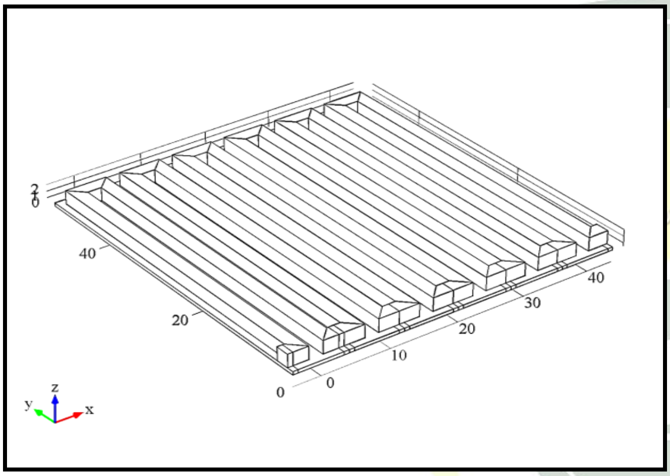

Fig. 1. Serpentine flow field PEMFC model.

III. Results and Discussions

The whole three dimensional serpentine flow field PEM fuel cell with several 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 50°C temperature and 1.0 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 concentration of Oxygen gases on cathode sideof the cell. The amount of Oxygen concentration of 7.7203mol/m^{3}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 concentration of Oxygen gases on cathode sideof the cell. The amount of Oxygen concentration of 7.6448mol/m^{3}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 concentration of Oxygen gases on cathode sideof the cell. The amount of Oxygen concentration of 7.7837mol/m^{3}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 concentration of Oxygen gases on cathode sideof the cell. The amount of Oxygen concentration of 7.6448 mol/m^{3}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 concentration of Oxygen gases on cathode sideof the cell. The amount of Oxygen concentration of 7.6448 mol/m^{3}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 concentration of Oxygen gases on cathode sideof the cell. The amount of Oxygen concentration of 8.4195mol/m^{3}was obtained corresponding to the cell potential of 0.9 V at a temperature 50°C.The effect of cathode Oxygen concentration on the cathode side in the serpentine flow field PEMFC for all cell potentials were illustrated in Fig.3in which the different cell potentials (V) were taken in x-axis and the cathode Oxygen concentration were taken in y-axis.

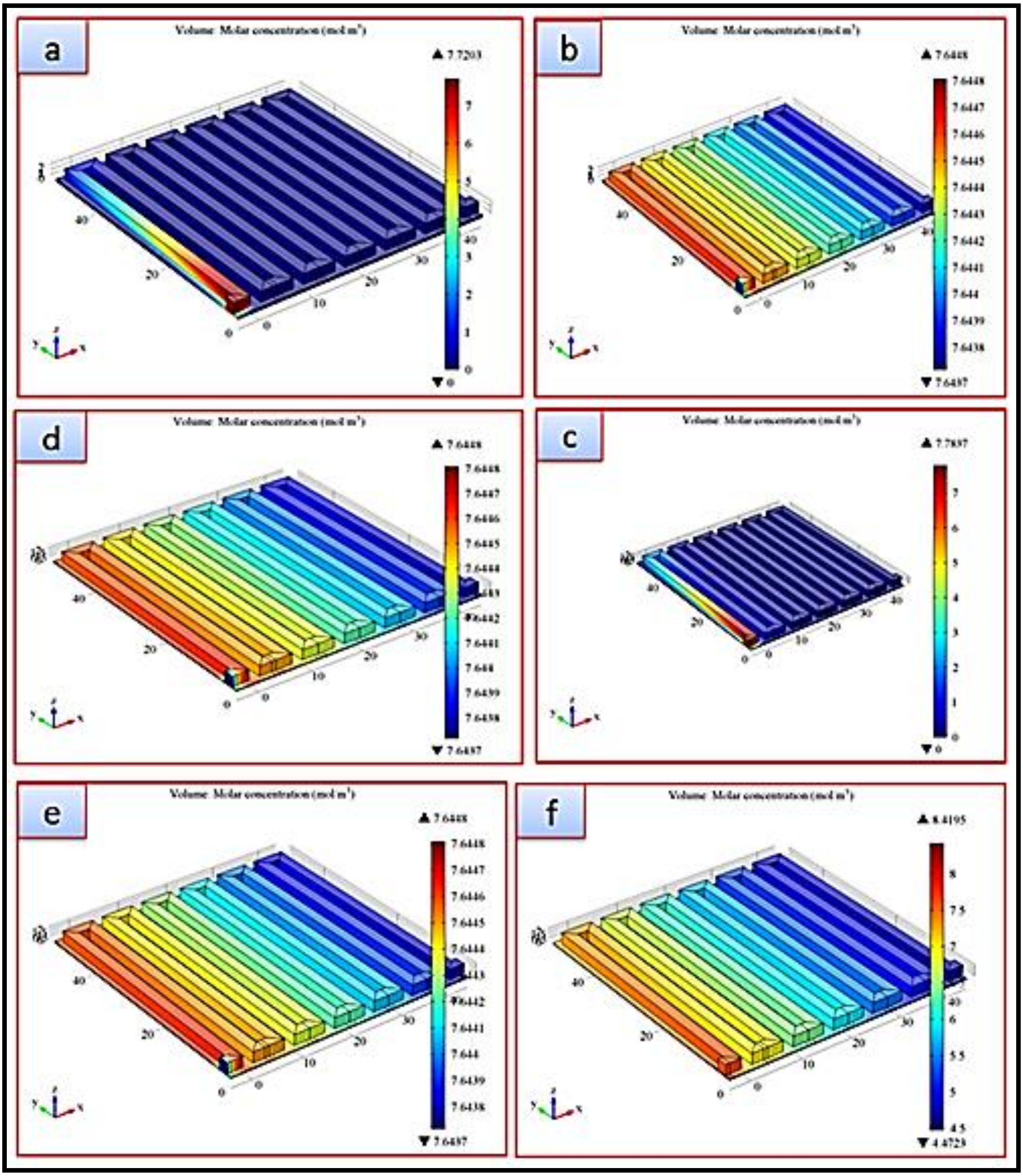

Fig. 2. Cathode Oxygen concentration at cell potential (a) 0.4V (b) 0.5V (c) 0.6V (d) 0.7V (e) 0.8V (f) 0.9V.

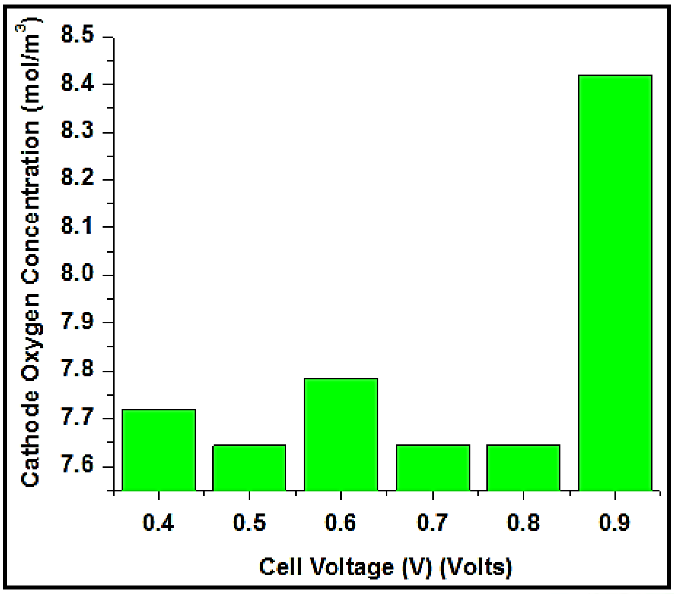

Fig. 3. Cathode Oxygen concentration for all cell potentials.

IV. SUMMARY

The highest oxygen distribution at cathode side was found in the cell at a cell potential of 0.9V. An effective distribution of oxygen concentration on cathode side had an adverse impact on the cell performance. The concentration of an Oxygen gas on the cathode side leads to increases the current density of the cell. Therefore, the cathode side oxygen effective distribution of oxygen gases is resulting in higher cell performance especially in the higher cell potentials. This work has demonstrated that distribution of oxygen gases on the cathode side at higher cell potentials can be used to improve the serpentine flow field PEM fuel cell performance. It was also found that the oxygen gases distribution at cathode side indeed improved the cell performances at higher cell potentials without modified the operating and design parameters of the cell.

REFERENCES

[1] Maher AR, Al-Baghdadi Sadiq. CFD models for analysis anddesign of PEM fuel cells. Nova Science Publisher, Inc.; 2008.

[2] Al-Baghdadi MARS, Al-Janabi HAKS. Effect of operatingparameters on the hydro-thermal stresses in protonexchange membranes of fuel cells. International Journal ofHydrogen Energy 2007; 32:4510-22.

[3] Kandlikar SG, Lu Z, Domigan WE, White AD, Benedict MW.Measurement of flow mal-distribution in parallel channelsand its application to ex-situ and in-situ experiments inPEMFC water management studies. International Journal ofHeat and Mass Transfer 2009; 52:1741-52.

[4] He W, Nguyen TV. A new diagnostic tool for liquid water management in PEM fuel cells using interdigitated flow fields. Chemical & Petroleum Engineering Department, the University of Kansas Lawrence; 2002. KS 66045.

[5] Su A, Weng F-B, Hsu C-Y, Chen Y-M. Studies on flooding in PEM fuel cell cathode channels. International Journal of Hydrogen Energy 2006; 31:1031-9.

[6] Cheng B, Minggao O, Baolian Y. Analysis of watermanagement in proton exchange membrane fuel cells.1007-0214 10/21. Tsinghua Science and Technology February2006; vol 11(1):54-64.

[7] Voss HH, Wilkinson DP, Pickup PG, Johnson MC, Basura V. Anode water removal; a water management and diagnostic technique for solid polymer fuel cells. Electro chemical Acta 1995; 40:321-8.

[8] Li Xianguo, Sabir Imran, Park Jaewan. A flow channel designprocedure for PEM fuel cells with effective water removal.Journal of Power Sources 2007;163:933-42.