CATHODE OXYGEN CONCENTRATION ON THE PEM FUEL CELL FOR VARIOUS CELL VOLTAGES

S.A.Srinivasan[1], S.Saran[2], K.Yogeswaran[3], S.Prasanth[4], D.Rudhra Prasad Sharma[5]

[1]*Assistant Professor,* [2]*UG Scholars, Department of Mechanical Engineering, Nandha College of Technology, Tamilnadu, India-638052.*

ABSTRACT

The proton exchange membrane fuel cell (PEMFC) is a predominantly encouraging energy conversion device for use in stationary or vehicular applications. PEMFCs deliver high efficiency and power density, with zero emissions, truncated operating temperatures, rapid start-up, and extended lifetime. Whereas the practice of PEMFCs has been on the increase, their commercialization has been slowed down by technical problems such as water saturating in their cathodes. This paper illustrates the Effect of Cathode oxygen Concentration on the PEM Fuel Cell for eleven cell voltages. The dissimilar liquid water transportation mechanisms in the flow channels, gas diffusion layers, catalyst layers, and membrane are modeled using the commercial modeling software. The model is used to examine the effect of cathode oxygen concentration under the different cell voltages on the performance of fuel cells with single flow channel configuration. The predictions show that for a cell voltage of 0.4 improves the oxygen concentration. Analyzed results shows that the PEM Fuel Cell with an operating voltage of 0.4 V yields the better distribution of oxygen on cathode side among other operating voltages.

Keyword: - *cathode oxygen concentration, single flow channel, PEM Fuel cell, cell voltages.*

1. INTRODUCTION

Increasing global energy requirements, localized power issues and the need for less environmental impact are now providing even more incentive to make fuel cells a reality. A number of technologies have been demonstrated to be feasible for generation of power from fuel cells over the last several years. Proton exchange membranes (PEM) have emerged as an essential factor in the technology race [1]. Proton-exchange membrane fuel cells (PEMFCs) are reflected to be an encouraging technology for capable power generation in the 21st century. Currently, proton exchange membrane fuel cells compromise several advantages, such as high proton conductivity, low absorptivity to fuel, low electro-osmotic drag coefficient, blameless chemical/thermal constancy, good mechanical properties and low cost [2]. The very high power density available from proton-exchange membrane (PEM) fuel cells combined with the potential for very low cost recommends the PEM fuel cell as the most possible power plant for the next generation, non-poisoning automobile engine [3]. There has been a recent interest in modelling the transient behavior of proton exchange membrane (PEM) fuel cells. In the past, there have been several electrochemical models which expected the steady-state behavior of fuel cells by appraising the equilibrium cell voltage for a particular set of operating conditions. These operating conditions included reactant gas deliberations and pressures, and operating current [4]. Conductance of gas, electrons, and protons must be augmented to provide well-organized transport to and from the electrochemical reactions. This is accomplished through careful attention of the volume of conducting media required by each phase and the scattering of the respective conducting network [5]. To meet the power density, reliability, and cost requirements that will enable a widespread use of fuel cells, many research activities focus on an understanding of the thermodynamics as well as the fluid mechanical and electrochemical processes within a fuel cell [6]. Water and thermal management on PEM fuel cell in the cathode depend on the current density, effective oxygen and hydrogen distribution, operating temperature, and cathode and anode humidification temperatures [7]. PEM fuel cell operates above the threshold current density, liquid water appears

and a two-phase zone forms within the porous cathode [8]. Comparison of the model results with experimental data and the existing two-dimensional model showed that accounting for the oxygen concentration variations along the channel and its effect on the current density is critical for accurately predicting the cathode performance. Variations in the current density along the channel were strongly influenced by the changes in oxygen concentration caused by consumption due to reaction and dilution caused by water evaporation. Operating conditions that resulted in minimal loss in oxygen concentrations resulted in a more uniform current density distribution along the channel [9]. The predicted amount of liquid water depends strongly on the prescribed material properties, particularly the hydraulic permeability of the GDL [10]. Flow distribution in both anode and cathode channels are significantly affected by the mass consumption patterns on the Membrane Electrode Assembly (MEA) [11]. The performance of the cathode was found to be dominated by the dynamics of liquid water, especially in the high current density range. Conditions that promote faster liquid water removal such as temperature, dryness of the inlet gas stream, reduced diffusion layer thickness, effective oxygen distribution and higher porosity improved the performance of the cathode [12]. With the increase of oxygen concentration, open potential of PEM fuel cell increases; the optimum flow rate of cathode reactant decreases with the increase of oxygen concentration in PEM fuel cell; the ohm region enlarges and concentration over-potential in U-I curve of PEM fuel cell decreases with the increase of oxygen concentration [13].

2. MODELING

Single flow channel's three dimensional models is created by using commercial modeling software with various modeling terms such as rib width, plate width, gdl height, channel length, channel height, channel width, membrane thickness, and gas diffusion layer thickness. After the successful completion of the three dimensional model the complete model is imported into commercial analysis software. The entire model is meshed with reasonable meshing elements to enhance the numerical results.

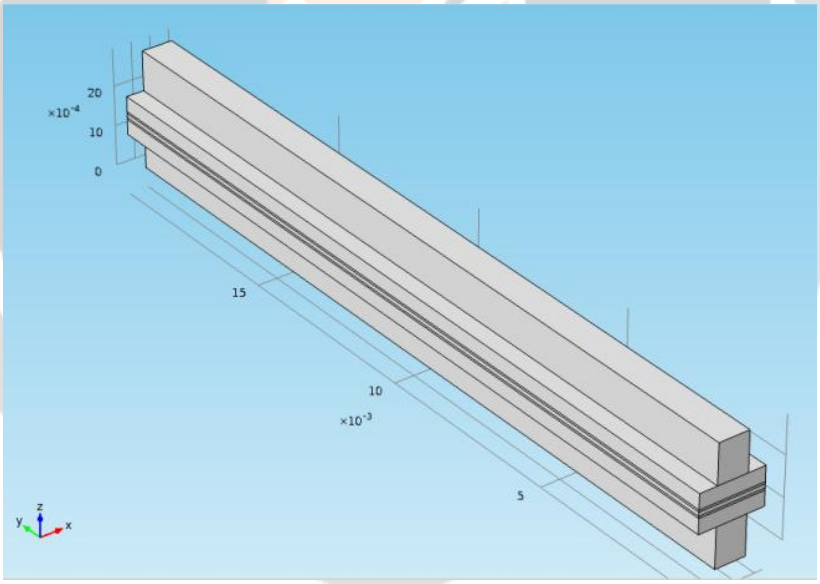

Fig-1: Isometric model

3. ANALYSIS

The mesh model of PEM fuel cell is analysed in commercial analysis software with different operating parameters like cell voltage, open circuit voltage, lumped anode resistance, membrane resistance, cell temperature, oxygen reference concentration, gdl porosity, gdl permeability, inlet H_2O mass fraction (cathode), inlet Oxygen mass fraction (cathode), inlet Hydrogen mass fraction (anode), inlet velocity, outlet 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, cathodic transfer coefficient are taken into account. The numerical results are obtained in the form of colour plots by clicking the compute domain for the eleven cell voltages.

4. RESULTS & DISCUSSIONS

The following numerically analyzed results are obtained from commercial analysis software for eleven cell voltages under different operating parameters. Fig.1 to Fig.11 depicts the numerically analyzed results of the distribution of oxygen at cathode side on single flow channel PEM fuel cell for the eleven cell voltages likely 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.70, 0.75, 0.8, 0.85 and 0.9V respectively. The PEM fuel cell with a cell voltage from 0.4V to 0.9V yields the effective distribution of oxygen on cathode side in the range of 1.825, 1.5782, 1.4027, 1.2740, 1.1782, 1.1061, 1.0556, 1.0221, 1.0038, 0.9960 and 0.9932 mol/m^3 respectively. Fig.12 shows the oxygen distribution on cathode side of the single flow channel PEM fuel cell for all cell voltages. It also illustrates the effective oxygen distribution on cathode side of single flow channel PEM fuel cells are virtuously depends upon the cell voltages. Increasing cell voltages are radically reduces the oxygen distribution on cathode side due to the huge consumption of oxygen.

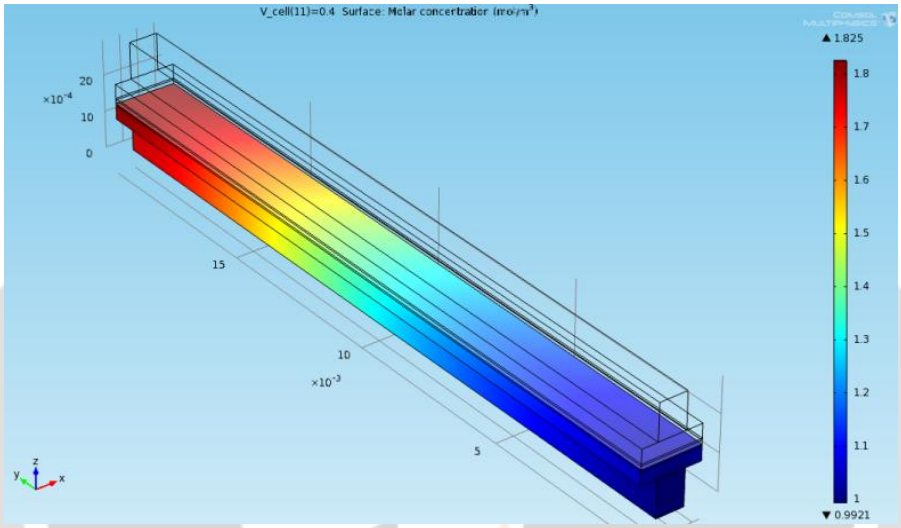

Fig-2: Oxygen distribution on cathode side at 0.4V

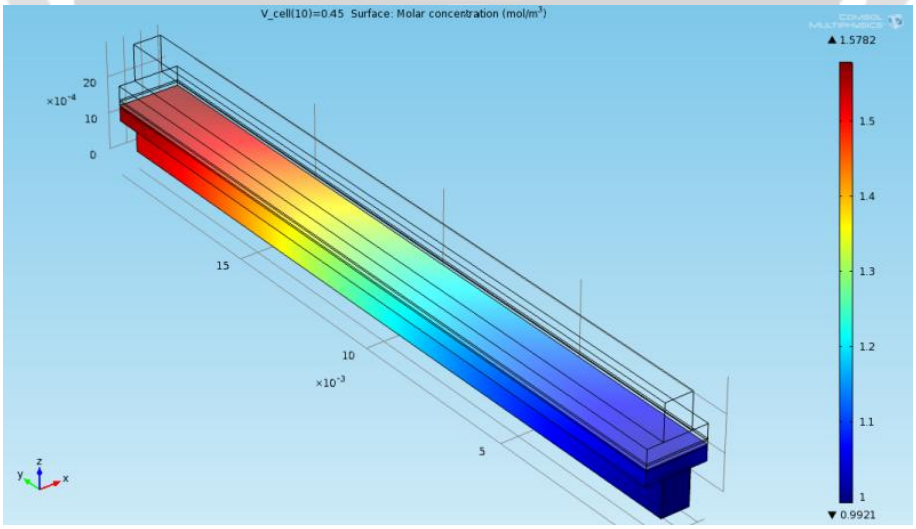

Fig-3: Oxygen distribution on cathode side at 0.45V

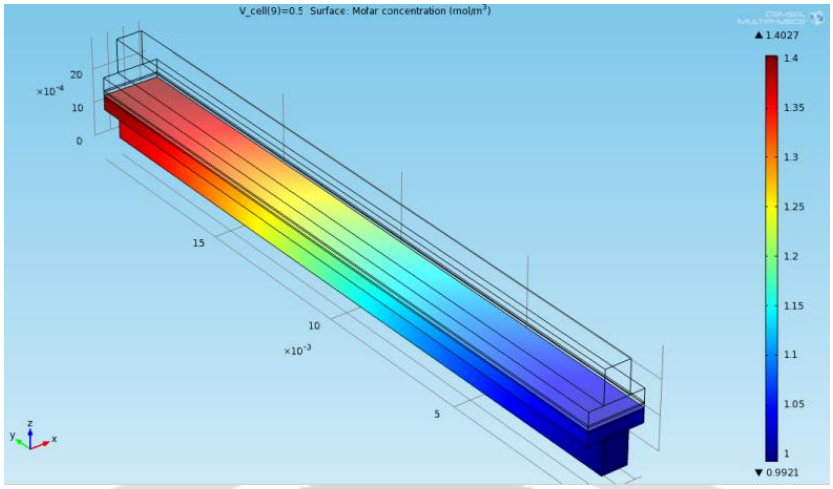

Fig-4: Oxygen distribution on cathode side at 0.5V

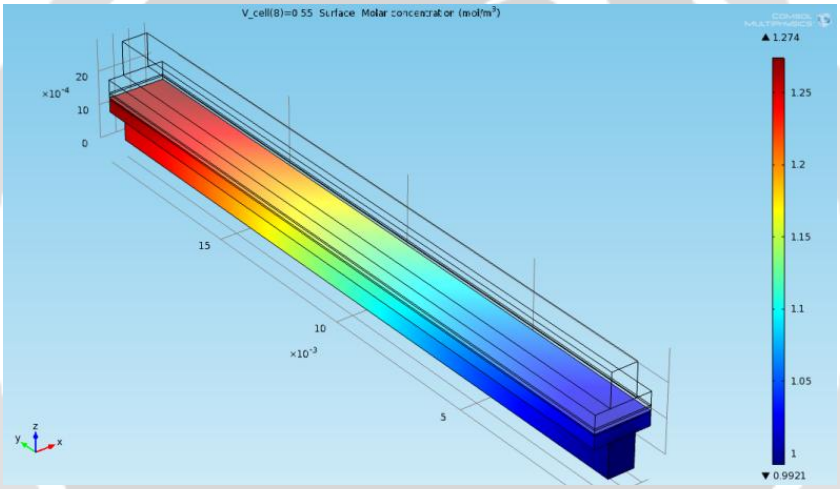

Fig-5: Oxygen distribution on cathode side at 0.55V

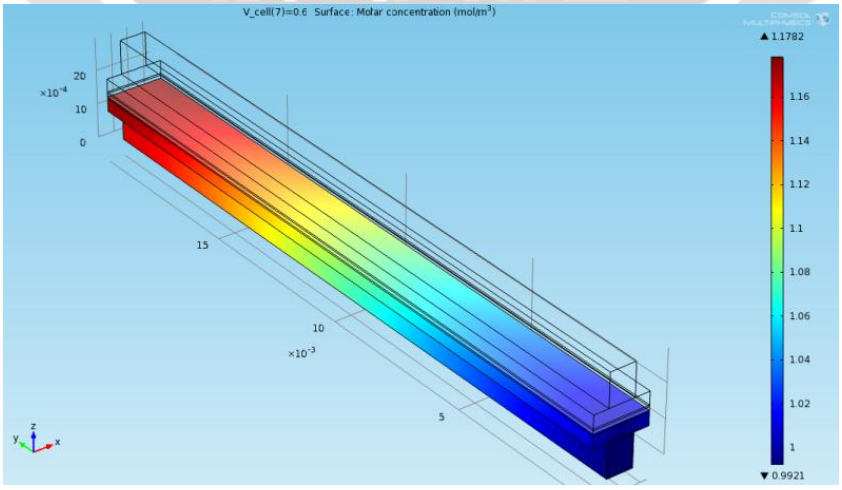

Fig-6: Oxygen distribution on cathode side at 0.6V

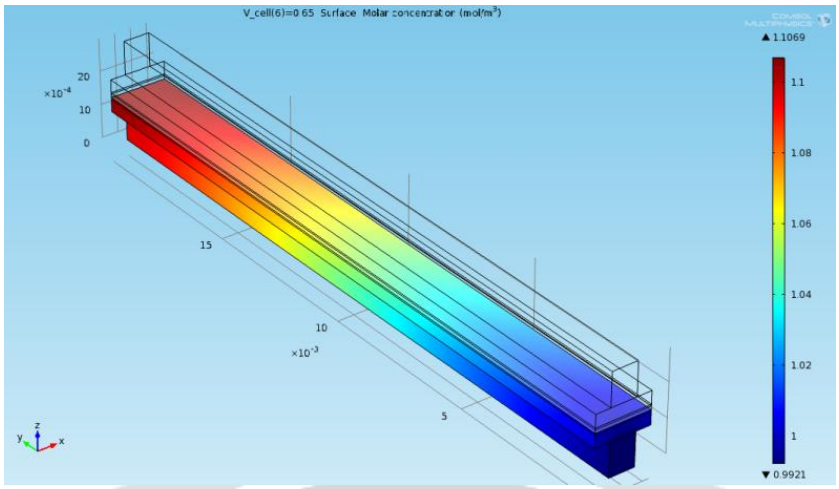

Fig-7: Oxygen distribution on cathode side at 0.65V

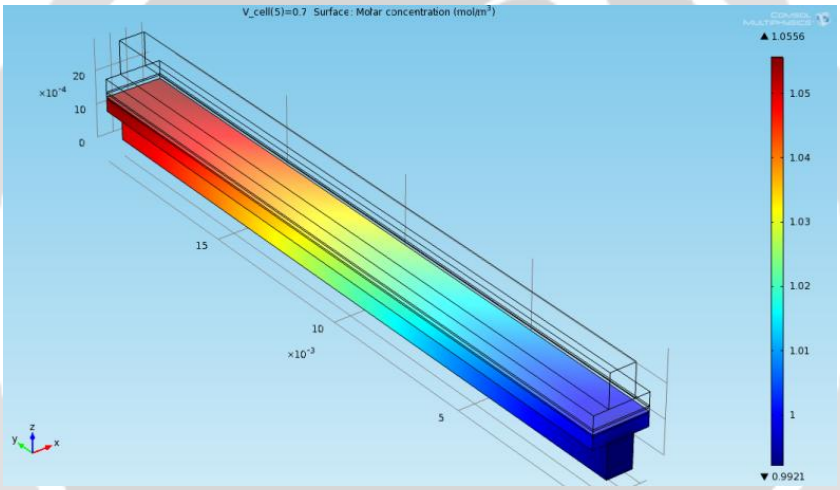

Fig-8: Oxygen distribution on cathode side at 0.7V

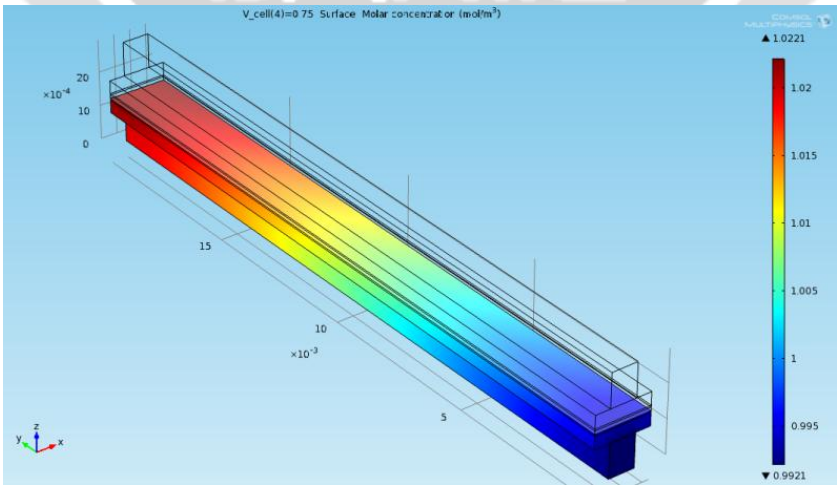

Fig-9: Oxygen distribution on cathode side at 0.75V

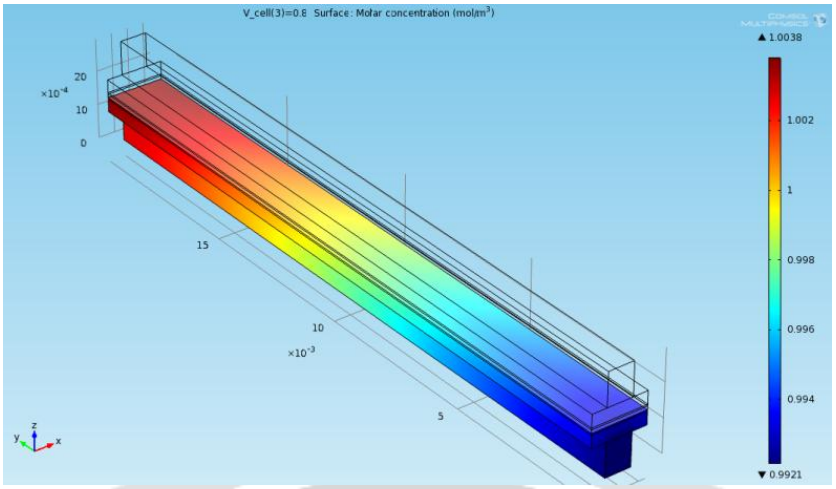

Fig-10: Oxygen distribution on cathode side at 0.8V

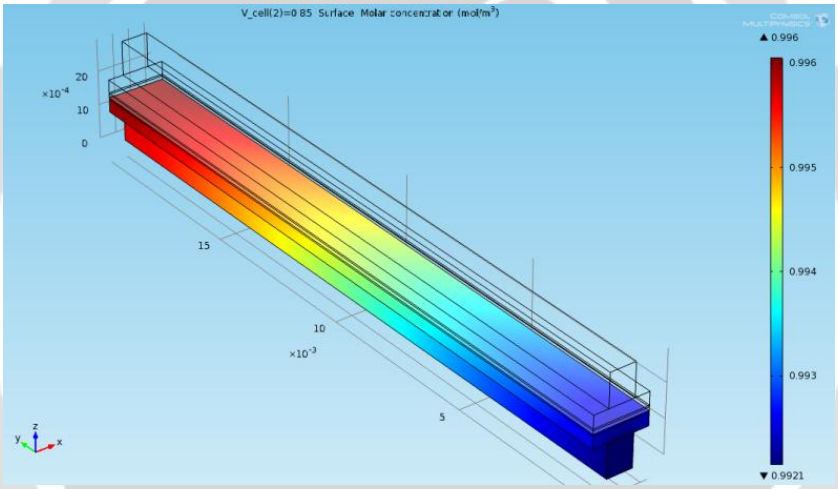

Fig-11: Oxygen distribution on cathode side at 0.85V

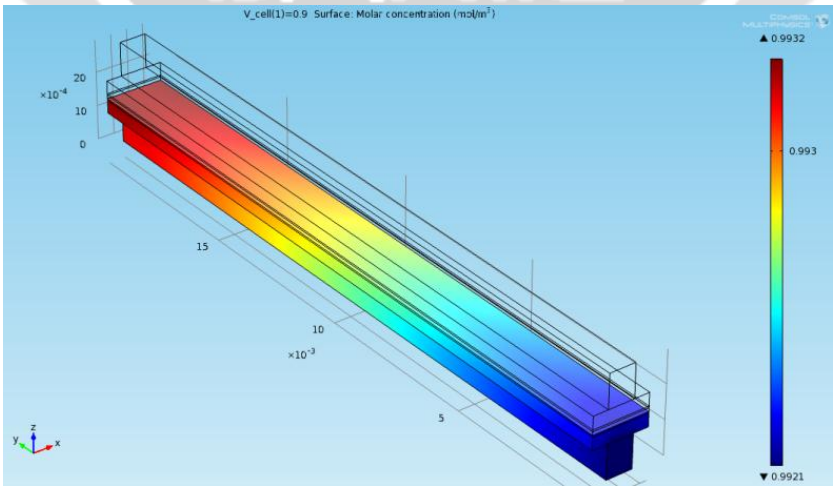

Fig-12: Oxygen distribution on cathode side at 0.9V

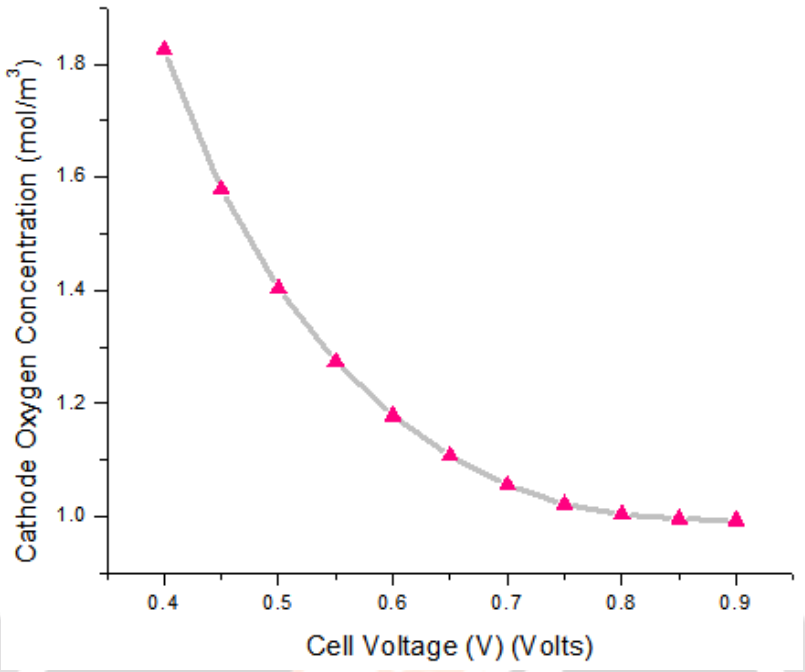

Fig-13: Cathode oxygen distribution for all cell voltages

SUMMARY

Single flow PEM fuel cell is selected for this numerical analysis to appraise its effective distribution of oxygen of the cell under eleven cell voltages. A number of design and operating parameters were taken into account and numerical analysis has been carried out successfully by using commercial analysis software. The analyzed numerical shows that the single flow channel PEM fuel cell with a cell voltage of 0.4V produces the maximum and better distribution of oxygen on cathode side of 1.825 mol/m^3 among the other ten cell voltages. It also represents distribution of oxygen on cathode side in single flow channel PEM fuel cells are bit by bit decreased with its increasing cell voltages.

REFERENCES

[1] Shoibal Banerjee and Dennis E. Curtin, Fluorine in Alternative Energy Sources Nafion® perfluorinated membranes in fuel cells, Journal of Fluorine Chemistry, 125 (8), 2004, pp. 1211–1216.

[2] Saswata Bose, Tapas Kuila, Thi Xuan Hien Nguyen, Nam Hoon Kim, Kin-tak Lau and Joong Hee Lee, Polymer membranes for high temperature proton exchange membrane fuel cell: Recent advances and challenges, Progress in Polymer Science, 36 (6), 2011, pp.813-843.

[3] Prater, Polymer electrolyte fuel cells: a review of recent developments, Journal of Power Sources, 51 (2), 1994, pp.129-144.

[4] Lei Zhang, Jiujun Zhang, David P. Wilkinson and Haijiang Wang, Progress in preparation of non-noble electro catalysts for PEM fuel cell reactions, Journal of Power Sources, 156 (2), 2006, pp.171–182.

[5] S. Litster and G. McLean, Review-PEM fuel cell electrodes, Journal of Power Sources, 130(2), 2004, pp.61-76.

[6] Jinfeng Wu, Xiao Zi Yuan, Haijiang Wang, Mauricio Blanco, Jonathan J. Martin and Jiujun Zhang, Review -Diagnostic tools in PEM fuel cell research: Part I Electrochemical techniques, International Journal of Hydrogen Energy, 33 (6), 2008, pp.1735-1746.

[7] Lixin You and Hongtan Liu, A two-phase flow and transport model for the cathode of PEM fuel cells, International Journal of Heat and Mass Transfer, 45 (11), 2002, pp.2277-2287.

[8] Dilip Natarajan and Trung Van Nguyen, Three-dimensional effects of liquid water flooding in the cathode of a PEM fuel cell, Journal of Power Sources, 115 (1), 2003, pp.66-80.

[9] T. Berning and N. Djilali, a Three Dimensional, Multiphase, Multicomponent Model of the Cathode and Anode of a PEM Fuel Cell, Journal of the Electrochemical Society,150 (12), 2003, pp.1589-1598.

[10] Sandip Dutta, Sirivatch Shimpalee and J.W. Van Zee, Numerical prediction of mass-exchange between cathode and anode channels in a PEM fuel cell, International Journal of Heat and Mass Transfer, 44 (11), 2001, pp.2029-2042.

[11] Dilip Natarajan and Trung Van Nguyen, a Two-Dimensional, Two-Phase, Multicomponent, Transient Model for the Cathode of a Proton Exchange Membrane Fuel Cell Using Conventional Gas Distributors, 148 (12), 2001, pp.1324-1335.

[12] Zhe Sun, Hong Sun, Lihua Luan and Zhengnan Jin, Influence of oxygen concentration on performance of PEM fuel cell, International Conference on Mechanic Automation and Control Engineering (MACE), June 2010, pp.3908-3911.

[13] Vijay A. Sethuraman, John W. Weidner, Andrew T. Haug, Sathya Motupally, and Lesia V. Protsailo, Hydrogen Peroxide Formation Rates in a PEMFC Anode and Cathode Effect of Humidity and Temperature, Journal of the Electrochemical Society, 155 (1), 2008, pp.50-57.