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Performance Studies on Single Flow Channel Proton Exchange Membrane Fuel Cell under Different Cell Potentials

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Abstract

The Proton Exchange Membrane Fuel Cell (PEMFC) performance is purely depends on the various geometrical and operating parameters. In this study a numerical investigation has been carried out on a single flow channel Proton Exchange Membrane Fuel Cell (PEMFC) with an operating cell potential of 0.4V to analyze the various performance and operating characteristics likely current density, anode water concentration, cathode water concentration, cathode oxygen concentration, anode hydrogen concentration, pressure distribution of reactant gases at gas diffusion layer, velocity distribution of reactant gases at gas diffusion layer at an operating temperature of 453K.

Keywords: PEMFC, single flow channel, performance, numerical analysis, COMSOL

I. INTRODUCTION

In the last era, fuel cells give the impression to be one of the most appropriate another course of action for generation of uncontaminated vitality and, among then, PEM fuel cells appear to be one of the furthermost trustworthy ones [1]. At present, voluminous investigation determinations emphasis on the enlargement of more competent PEMFC that yields extraordinary current densities for longer operational periods [2]. The effects of a underprivileged or misdistribution of reactants in PEM stack flow fields is reflected a fundamental dispute to be engaged into account, as it front-runners to non-uniform current density, confined to a small area hot spots in the membrane, performance degradation, and material poverty [3]. In universal misdistribution in equivalent channels may be caused, surrounded by others, by irregular flow conflicts in the parallel channels produced by dissimilarities in channel proportions, different flow lengths, bumpy fouling, density and viscosity deviations, and being there of two or more phases due to water content in the channels [4]. The absence of an investigational practice to extent the prompt flow circulation is approximately that prerequisite to be overcome, though it may characterize a tremendously difficult issue for PEM stacks systems [5, 6]. Other researchers [7, 8] have absorbed their numerical studies to appraise the stimulus of the flow field geometry on the pressure drop dissimilarity and stream circulation in a PEM stack. They determined that in cooperation the channel battle and the rip widths (space between channels) can boost the consistency of the flow circulation. However larger rip width may comprise a better solution for flow distribution because growing the channel conflict requires a disproportionate pressure drop which is not advantageous in practical applications.

II. MODELING

The COMSOL Multiphysics software is used to create the complete model of single flow channel PEM fuel cell. The entire three dimensional model is shown in figure.1. A fuel cell with 150 mm reactive area single flow channel was considered. Generally a typical 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 complete three dimensional model of the single flow channel PEM fuel cell geometry in the necessary coordinate location. Next the complete three dimensional model of single flow channel PEM fuel cell had been created by reclaiming the data from modeling terms table in the software. Next the not the same 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 H2O, 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 single flow channel PEM fuel cell under a cell potential of 0.4V. The PEMFCs were functioned at a temperature of 453K and an operating pressure of 1.0 bar respectively.

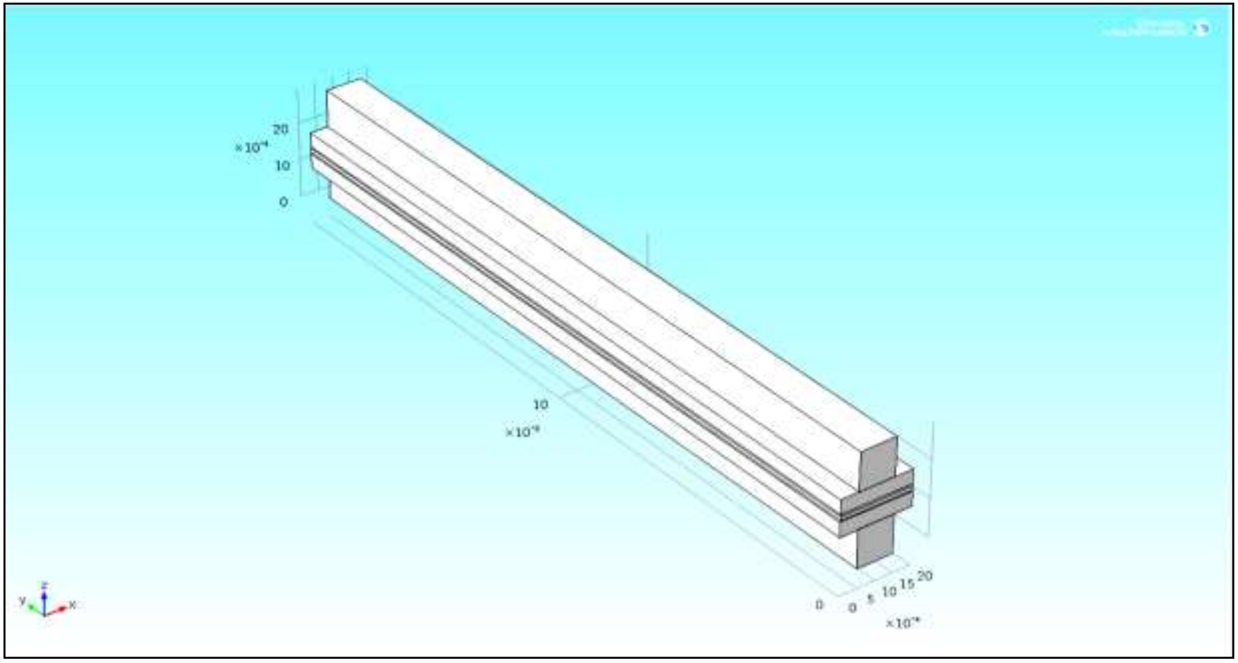

Fig. 1: Three-dimensional model of single flow channel PEMFC

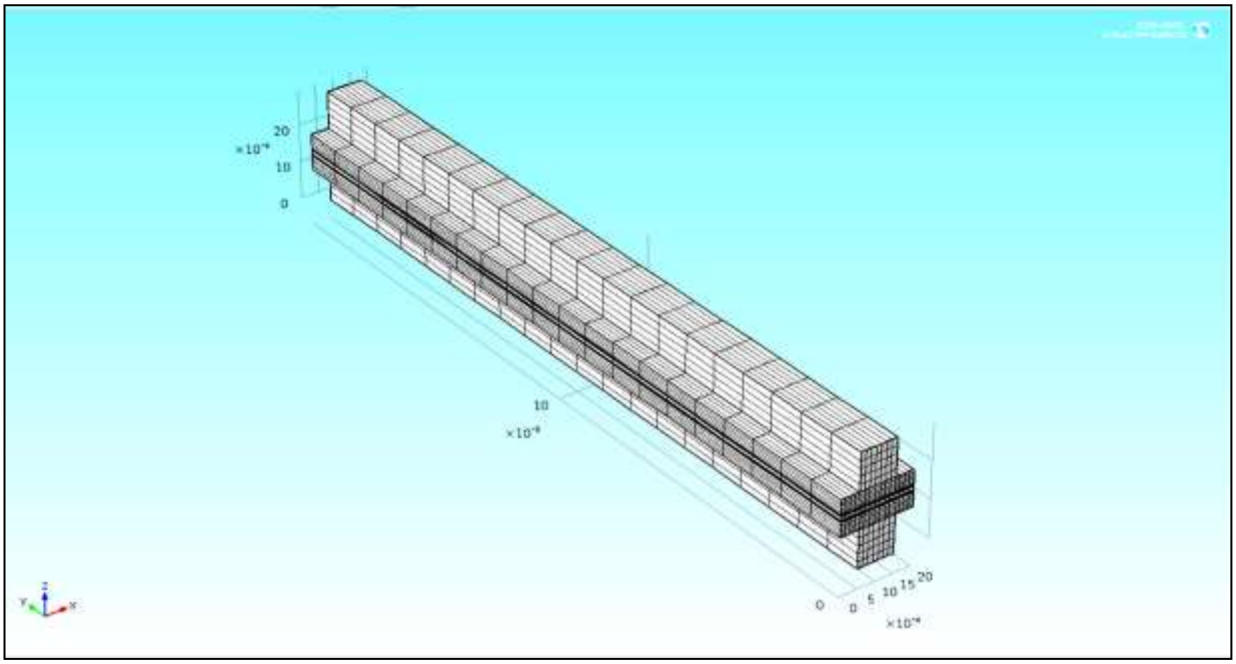

Fig. 2: Mesh model of single flow channel PEMFC

III. RESULTS AND DISCUSSIONS

The overall three dimensional single flow channel PEM fuel cell several modeling modules like membrane, anode and cathode catalyst layers, anode and cathode GDL, anode and cathode flow channels was operated at an operating conditions of 453K temperature, 1.0 bar pressure and a cell voltage of 0.4V. In the start the single flow channel PEM fuel cell was involved to evaluate the various performances and operating characteristics likely current density, power density, anode water concentration, cathode water concentration, cathode oxygen concentration, anode hydrogen concentration, pressure distribution of reactant gases at gas diffusion layer, velocity distribution of reactant gases at gas diffusion layer a cell voltage of 0.4V. The amount of anode water concentration of the single flow channel PEMFC is 5.4338 mol/m^3 was obtained corresponding to the cell potential of 0.4 V at a temperature 50°C. Next the amount of cathode water concentration of the single flow channel PEMFC is 25.813 mol/m^3 was obtained corresponding to the cell potential of 0.4 V at a temperature 50°C. Next the amount of cathode Oxygen concentration of the single flow channel PEMFC is 1.5701 mol/m^3 was obtained corresponding to the cell potential of 0.4 V at a temperature 50°C. Next the pressure distribution of reactant gases at the gas diffusion layer inside the single flow channel PEMFC was obtained corresponding to the cell potential of 0.4 V at a temperature 50°C which is relatively higher value of 7.82 Pa. Next the velocity distribution of reactant gases at the gas diffusion layer inside the single flow channel PEMFC was obtained corresponding to the cell potential of 0.4 V at a temperature 50°C which is relatively greater value of 0.743 m/s. The membrane current density of 8637.9 A/m^2 is obtained inside the single flow channel PEMFC at a 0.4 V at a temperature 50°C which is much higher than the other cell potentials.

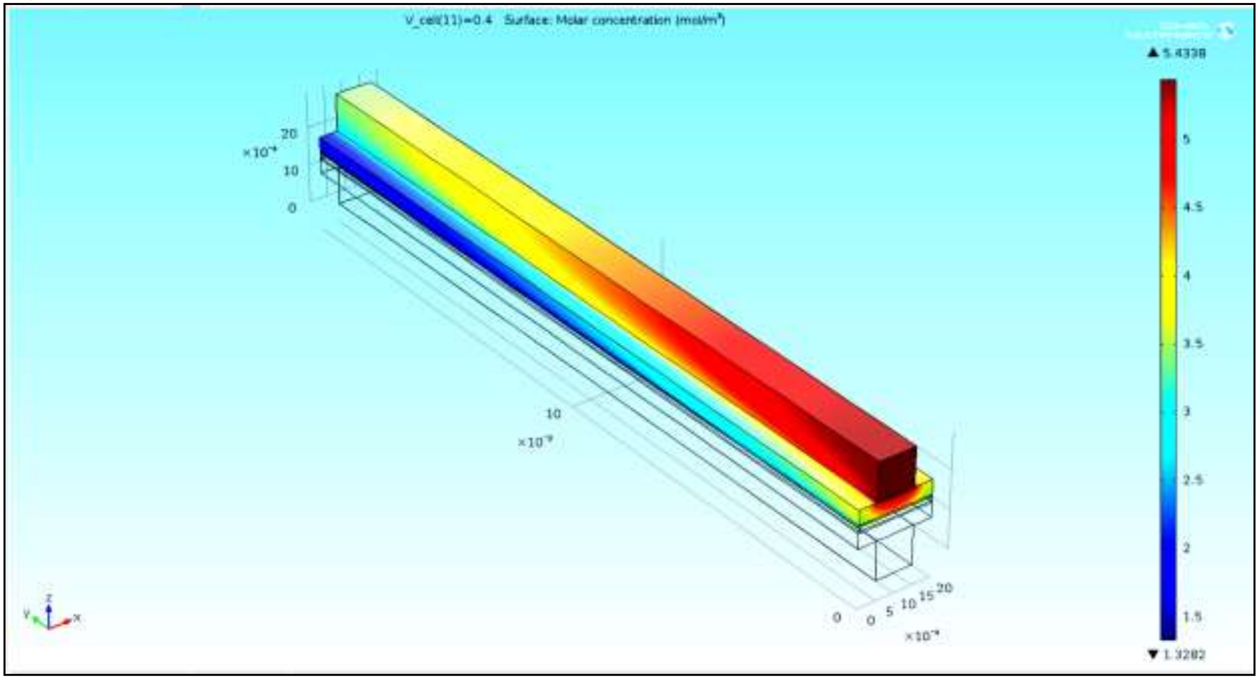

Fig. 3: Anode water concentration at 0.4V cell potential

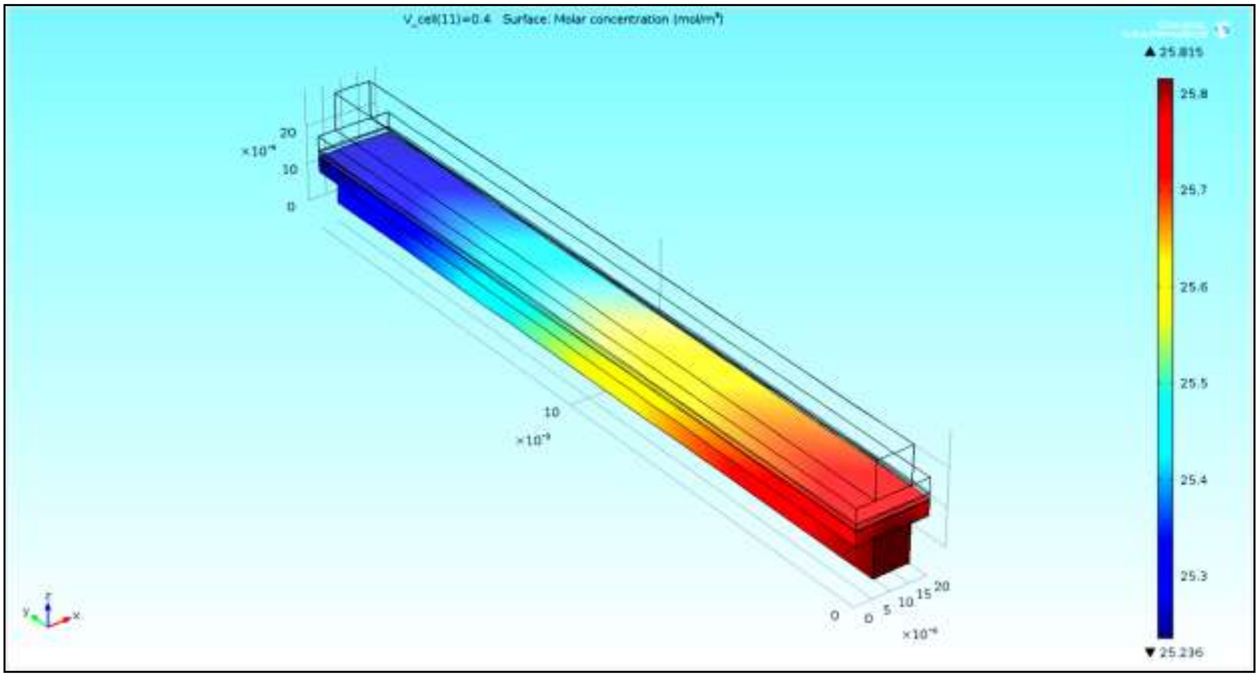

Fig. 4: Cathode water concentration at 0.4V cell potential

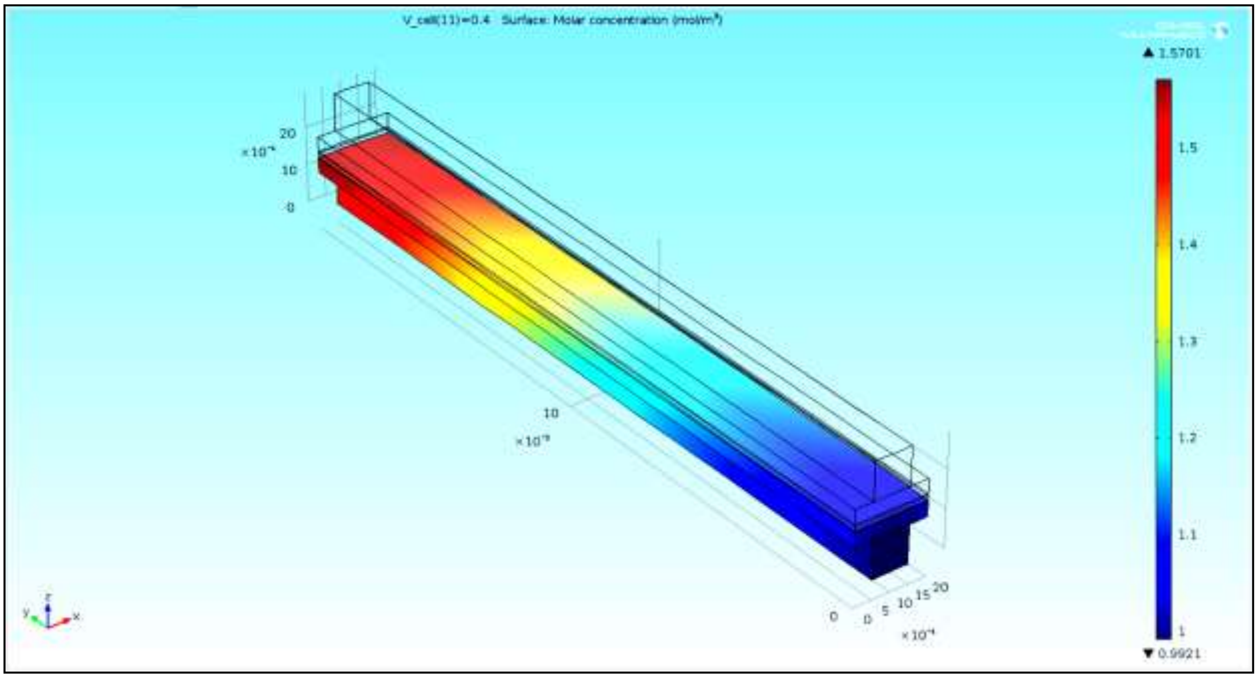

Fig. 5: Cathode Oxygen concentration at 0.4V cell potential

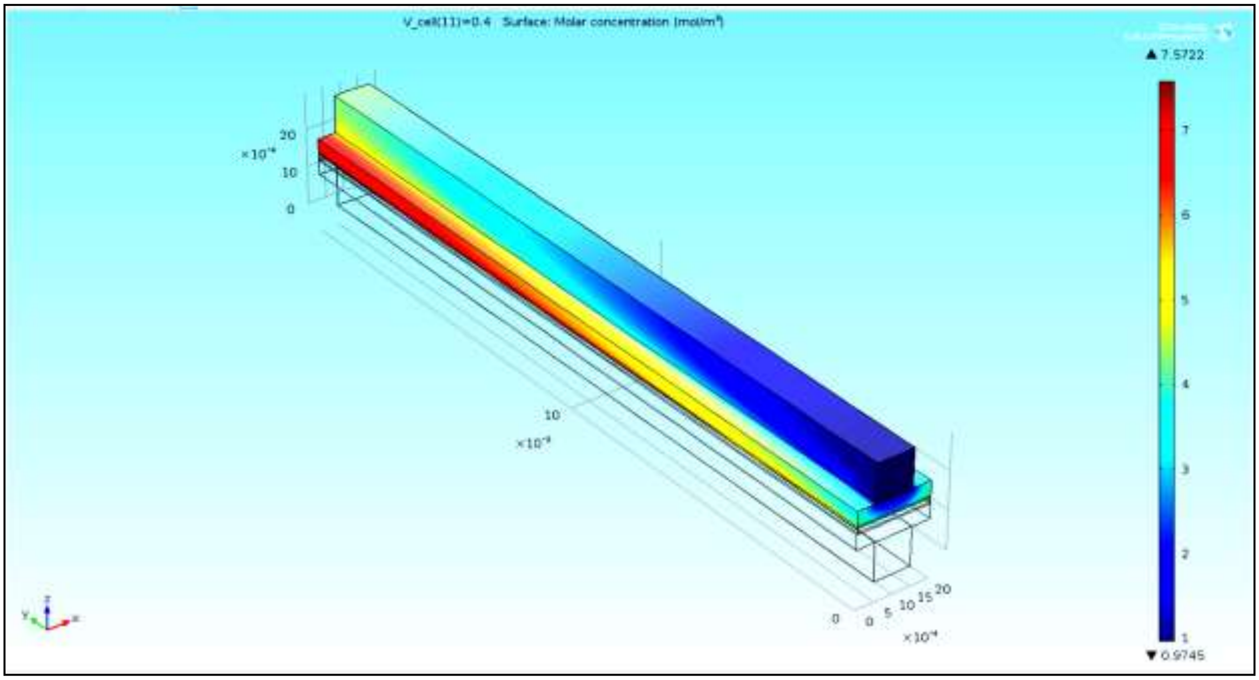

Fig. 6: Anode Hydrogen concentration at 0.4V cell potential

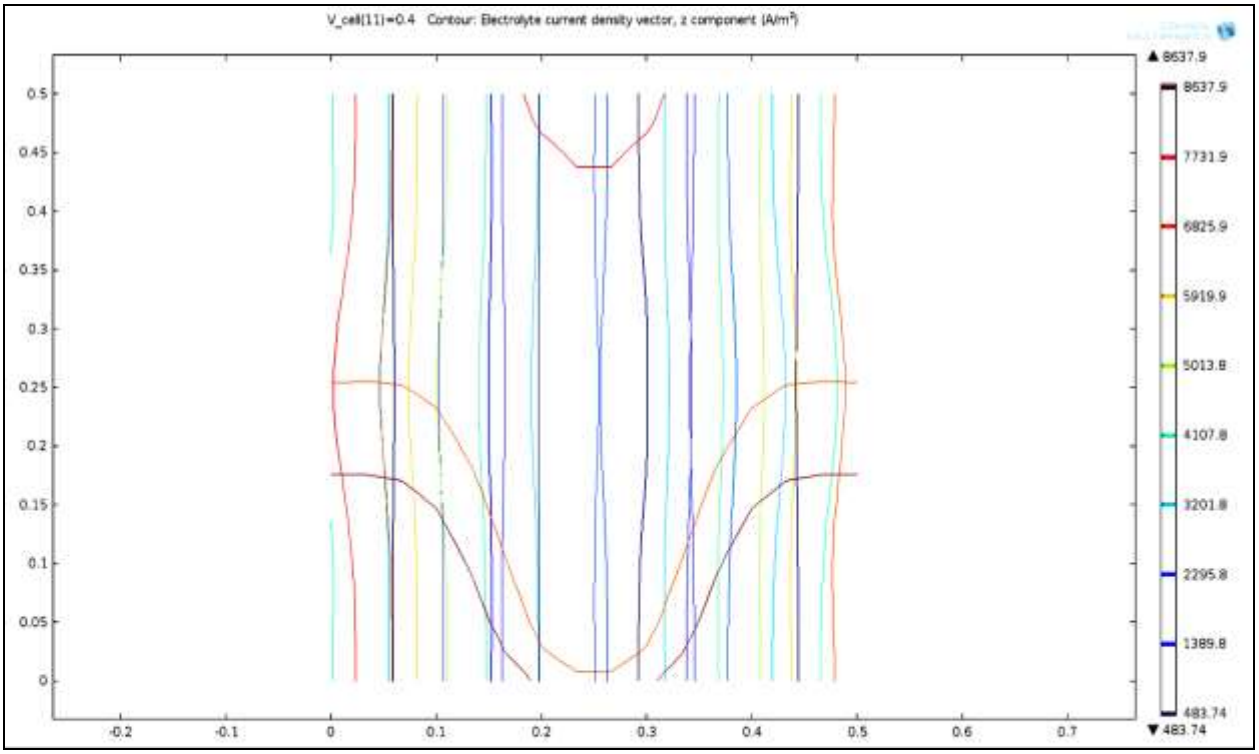

Fig. 7: Current density at 0.4V cell potential

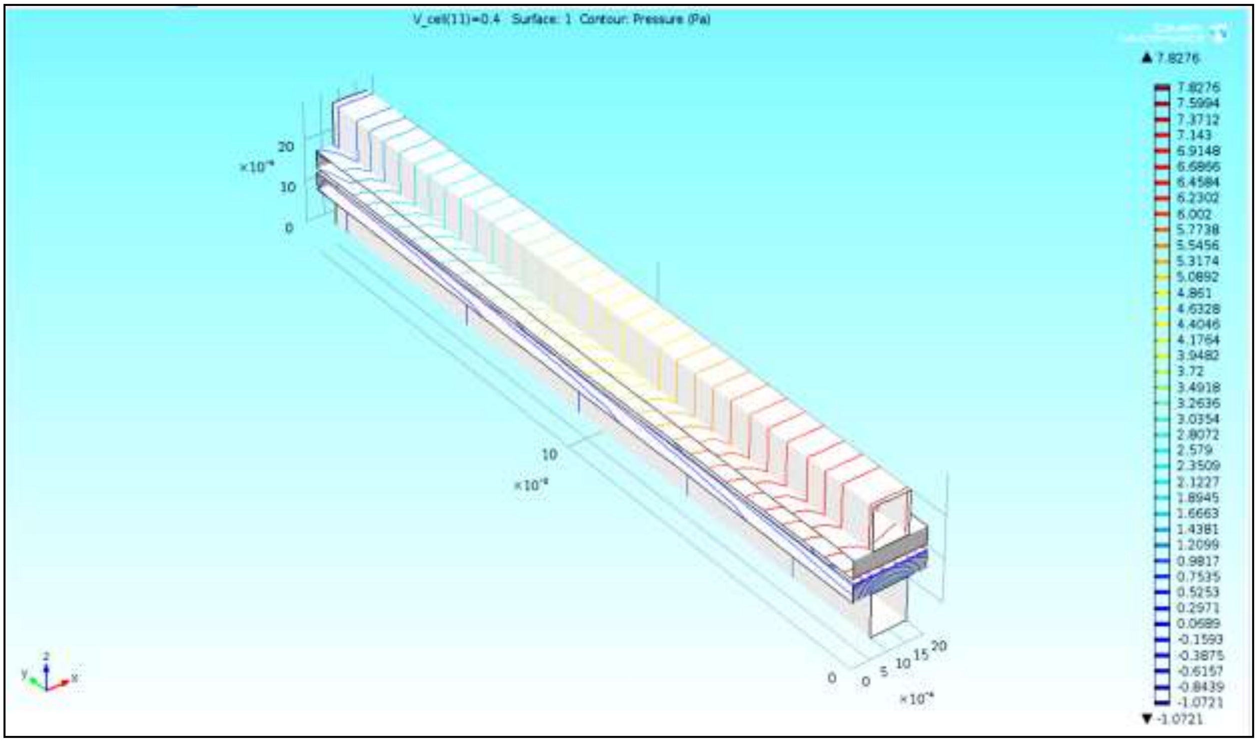

Fig. 8: Pressure distribution at 0.4V cell potential

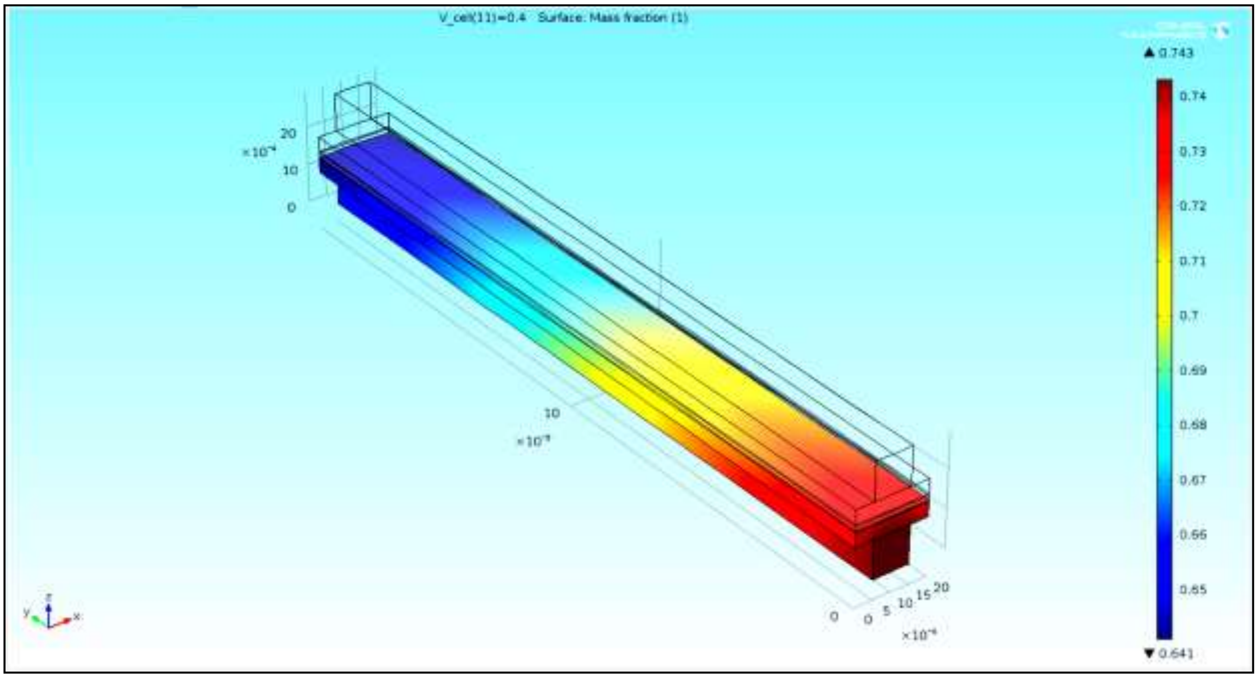

Fig. 9: Velocity distribution at 0.4V cell potential

IV. SUMMARY

A typical numerical analysis has been carried out on a single flow channel PEM fuel cell to analyze the adverse effect of cell potentials to analyze the various performance and operating characteristics likely current density, anode water concentration, cathode water concentration, cathode oxygen concentration, anode hydrogen concentration, pressure distribution of reactant gases at gas diffusion layer, velocity distribution of reactant gases on a single flow channel PEM fuel cell at an operating temperature of 453K. The highest gas diffusion layer velocity distribution of the reactant gases was found in the cell at a cell potential of 0.4V. An effective distribution of reactant gases at gas diffusion layer had an adverse impact on the cell performance. The reactant gages 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. 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 single flow channel PEM Fuel cell.

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