Performance Analysis of High Temperature PEM Fuel Cell with Single Flow Channel Configuration

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***Abstract*— The performance of a Proton Exchange Membrane Fuel Cell (PEMFC) is greatly affected by the geometrical and operating parameters. The flow channels are used for uniform reactant distribution throughout the active area of fuel cell. This paper numerically investigates the effects of temperature change in single flow channel high temperature PEMFC. The Numerical model of single flow channel high temperature PEM fuel cell was developed and analyzed by using COMSOL Multiphysics 4.2 software package. Different operating voltages and operating temperatures were taken to optimize the performance of high temperature PEMFC. Numerical results shown that the PEMFC with an operating temperature of 453K at an operating voltage of 0.4 V gives the better performance compared with other four operating temperatures. From the numerical results performance and polarization curves were drawn and the power densities of single flow channel high temperature PEMFC with five different operating temperatures were compared with each other.**

Keywords—High Temperature PEM Fuel Cell, Single Flow Channel Performance, COMSOL.

I. INTRODUCTION

Due to the growing concerns on the depletion of petroleum based energy resources and climate change, fuel cell technologies have received much more attention in recent years owing to their high efficiencies and low emissions [1]. The proton Exchange membrane (PEM) fuel cell performance not only depends on the operating parameters like temperature, pressure and back pressure on anode and cathode flow channels, but it also depends on design parameters like channel width to rib width, channel depth and number of passes on the flow channel [2]. The three dimensional model of serpentine flow field having 2 pass, 3 pass and 4 pass along with Gas diffusion Layer, Catalyst and membrane were analysed by keeping the same size of rib and channel by using COMSOL software. Same procedure has been followed to carry out to evaluate the performance of high temperature PEM fuel cell with single flow channel configuration with the modification of geometry and operating parameters by using COMSOL software to analyze its performance [3]. Also, some recommendations that can be implemented in optimizing the design of PEMFC flow fields for maximum performance are mentioned. Regarding the cross section shape of the channels, although channels with semicircular, trapezoidal, triangular, etc. sections have been studied, rectangular cross section has been the channel's most widely used configuration [4]. Hence, it is clearly shows that there is an important need of analyzing the important influence of operating and design parameters. In this paper, numerical investigation has been carried out to evaluate the effects of temperature change in single flow channel high temperature PEMFC on cathode side with same size of rib and channel sizes, gas diffusion layer, catalyst layer and membrane were modelled, meshed and analyzed using COMSOL Multiphysics 4.2 software package.

II. MODELING

Flow channel configuration is the important consideration in channel design. Compared with other flow channel designs PEMFC with single flow straight channels yield better performance and lower pressure drop. So in this study the flow field design with different operating temperatures were considered. COMSOL software package is used in this project is to create and analyze the different input and output parameters of "PEMFC domains". Creation of model is starts with the "PEMFC adding domains" then it moves to the 3D, steady state, single flow channel model. In "advanced description domains", the required geometries were generated with respect to the concern geometry parameters like (Channel Length, channel height, rib width, etc.). The Cartesian coordinates were used to define the entire geometry in the required coordinate position.

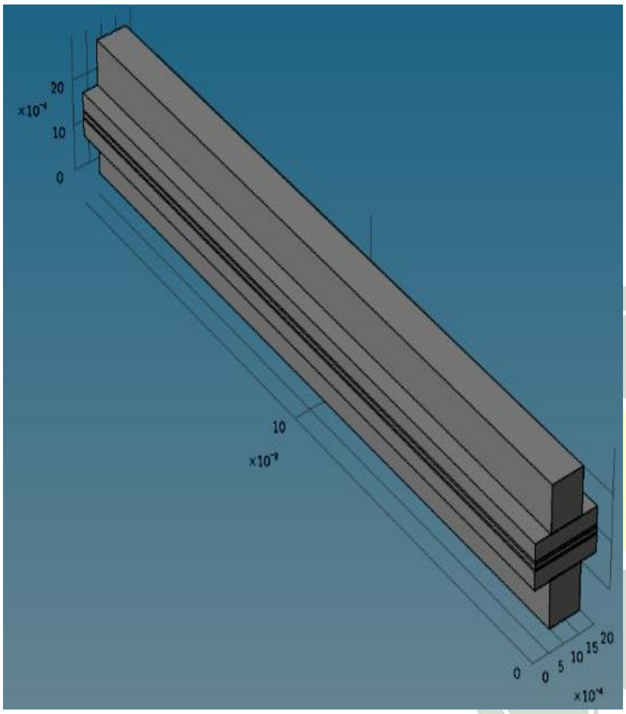

Fig. 1. High temperature single flow channel PEMFC isometric model

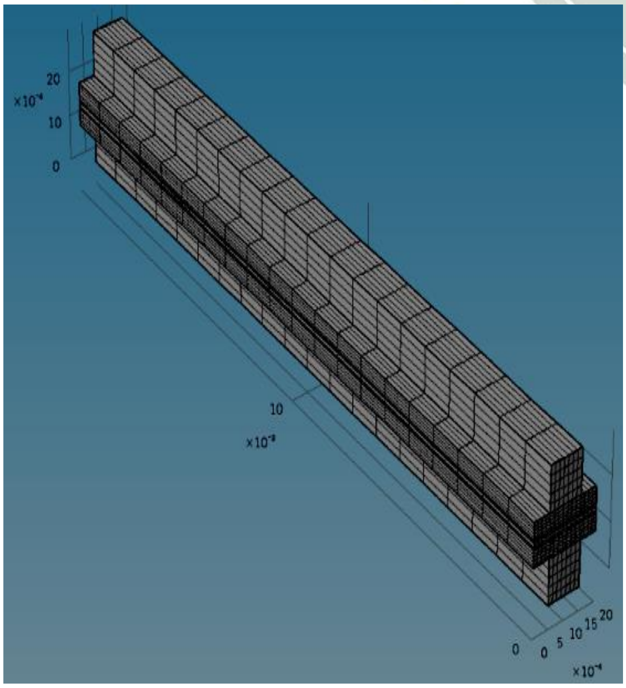

Fig.2. Mesh model of high temperature single flow channel PEMFC

Finally model had been created by recalling the data from design parameters table. By using concentrated species adding's domain the flow and the mass transport properties were modelled. The simulation has been solved by simultaneous equations like conservation of mass, momentum, energy, species, etc... The model used to consider the system as three-dimensional and steady, the inlet gases as ideal gases, the system as an isothermal, the flow as laminar, the fluid as incompressible, the thermo physical properties as constant and the porous GDL, the two catalyst layers and the membrane as an isotropic.

A. Design Parameters

The following design parameters have been taken into account to carry out the numerical analysis. The length of the channel is 0.02 m, channel height of 1×10^{-3} m, channel width of 1×10^{-3} m, rib width of 1×10^{-3} m, gdl height of 3.8×10^{-6} m, electrode height of 50×10^{-6} m, membrane height of 100×10^{-6} m.

III. Analysis

Single flow channel analysis starts with defined boundary conditions using the "explicit command" and this command executes the three dimensional geometry at different geometrical parameters domains.

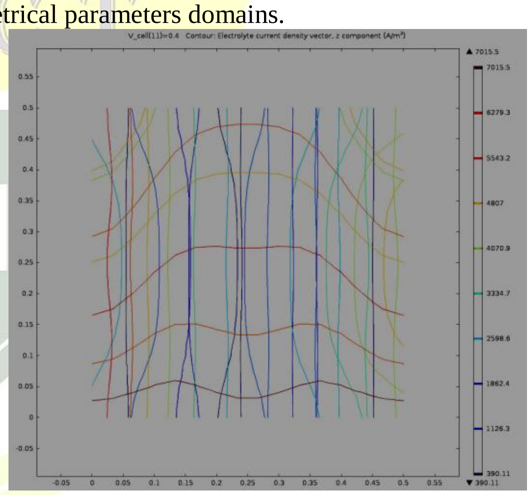

Fig.3. Membrane current density at 190°C

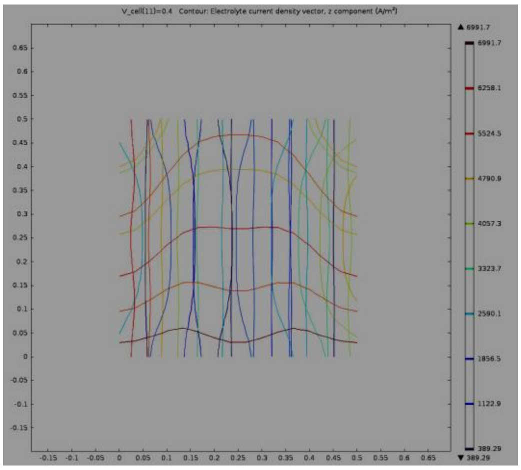

Fig.4. Membrane current density at 200°C

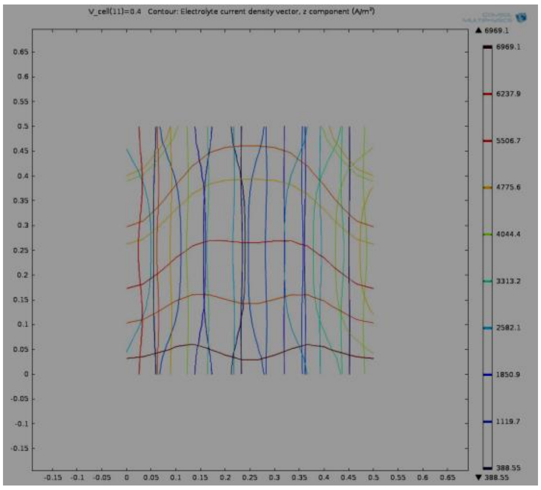

Fig.5. Membrane current density at 210°C

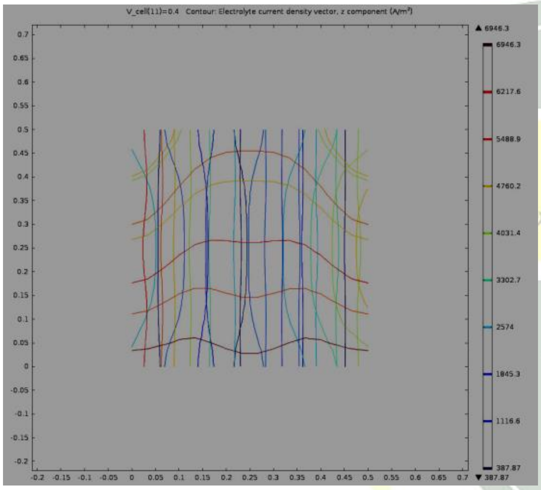

Fig.6. Membrane current density at 220°C

IV. Results and Discussions

From the above numerical analysis of the single flow channel high temperature PEMFC models using COMSOL software package, the current values corresponding to the cell voltages were obtained for five different operating voltages. Current density is the current generated per unit active area, whereas the power density is the power generated per unit active area. The polarization curve is the curve drawn between the current density and the voltage, whereas the performance curve is the curve drawn between current density and the power density. The current density is the ratio between the current that can be drawn from the cell corresponding to the particular voltage by the fuel cell and the unit active area. These polarization and performance curves are used to find the efficiency of the each fuel cell system. From this analysis, the high temperature PEM fuel cell with an operating temperature of 453K has the maximum current density of 0.40 V cell voltage at 0.65888 A/cm^2 of current density with a maximum peak power density of 0.2636 W/cm^2.The different power densities for five operating temperatures of high temperature PEM fuel cell model is given in the table.1. Performance curves of high temperature PEM fuel cell model is shown in the fig.11.

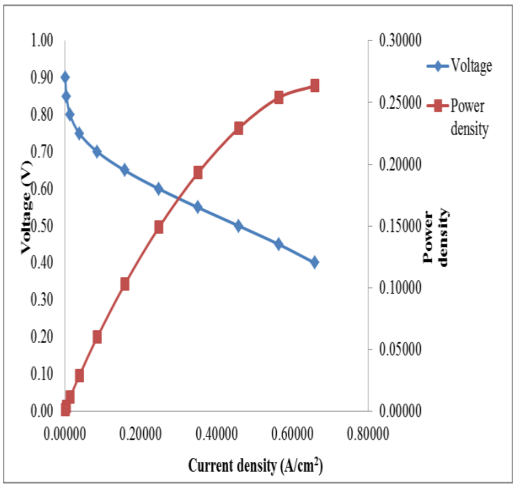

Fig.7. Performance curves at190°C operating temperature

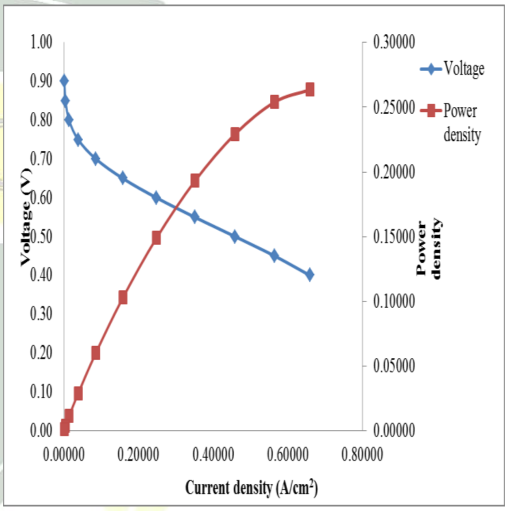

Fig.8. Performance curves at 200°C operating temperature

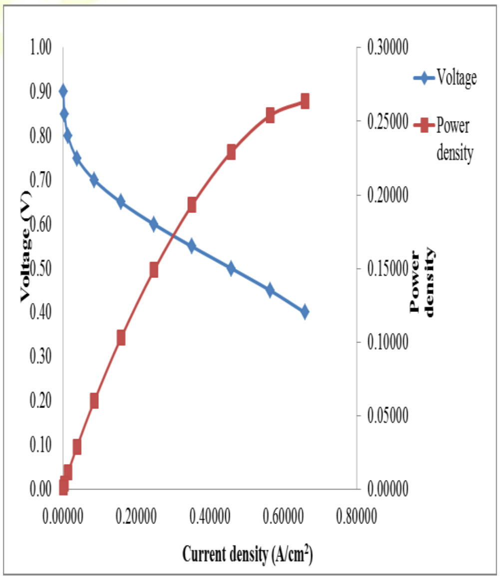

Fig.9. Performance curves at 210°C operating temperature

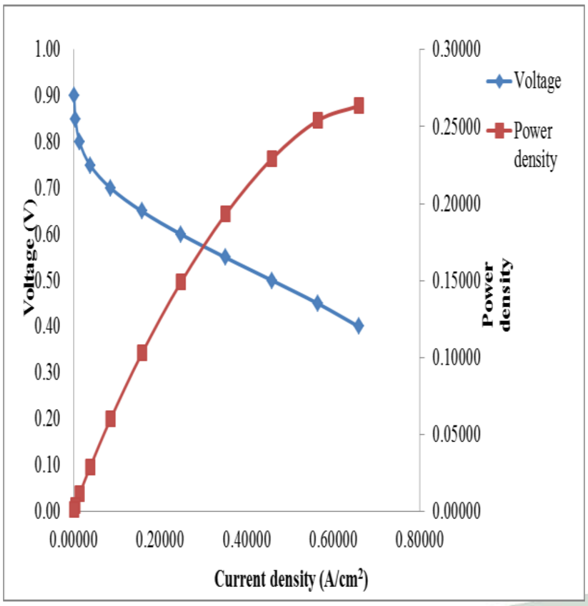

Fig.10 Performance curves at 220°C operating temperature

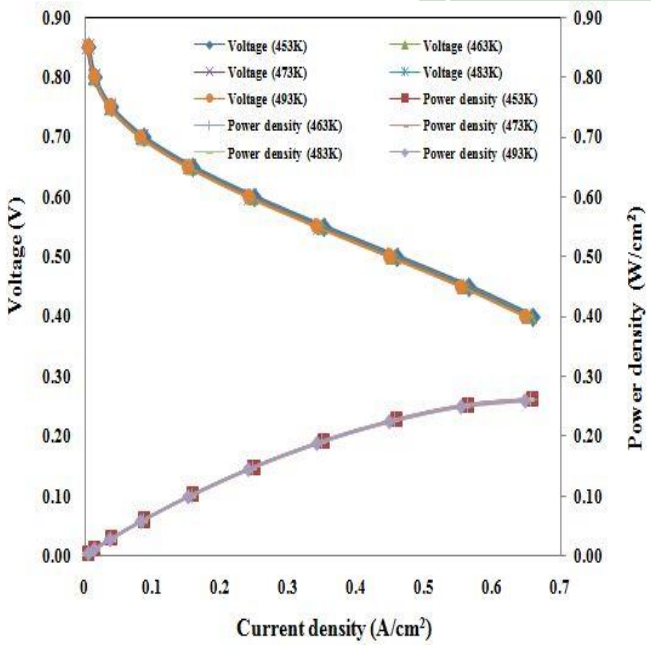

Fig. 11. Performance curves for all temperatures

TABLE 1 PEAK POWER DENSITIES FOR FIVE DIFFERENT OPERATING TEMPERATURES

Cell Voltage (V)	Power Density (P)				
	453K	463K	473K	483K	493K
0.4V	0.2636	0.2625	0.2615	0.2614	0.2594

V. SUMMARY

The three dimensional model of single flow channel high temperature PEM fuel cell with Gas diffusion Layer, Catalyst and membrane were analysed by keeping the same size of rib and channel. From the performance curves of each operating it was found that the maximum power density were obtained at an operating temperature of 453K when the fuel cell models were operated at the cell voltage of 0.40 V. From the above numerical results it is concluded that the high temperature PEMFC single flow channel configuration yields almost same power density as there is no much difference in the active area of the each operating temperatures. In future the operating parameters of the fuel cell like temperature, pressure etc. can be varied with changing of flow field geometry design.

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