Performance Analysis of PEM Fuel Cell with Three Passes Curved Serpentine Flow Field Design

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Abstract*— The Performance of PEM fuel cells is greatly influenced by the design and operating parameters. Effective distribution of reactants into the flow fields are carried out by the flow channels. So, flow channel geometry and flow field design contributes a crucial role of fuel cells performance. The Serpentine flow field gives the better performance when compared with other flow field design. In this analysis PEM fuel cell with three passes curved serpentine flow field design is selected to investigate the effect of its performance for the different cell voltages (0.25, 0.35, 0.45, 0.55, 0.65 V). Analyzed results show that the PEM fuel cell with three passes curved serpentine flow field design gives the maximum membrane current and power density at a cell voltage of 0.25 V and 0.65 V respectively. Among the other four cell voltages fuel cell with a cell voltage of 0.25 V yields the better operating characteristics like gas diffusion layer's pressure and velocity distributions and cathode oxygen concentrations.

Keywords*— *PEMFC, curved serpentine flow field, three passes, membrane current density, power density.

I. INTRODUCTION

As the number of fossil fuel based power generator systems has increased in various applications, the necessity for a viable alternative has captured worldwide attention. The automakers and industrial developers are investigating many possible solutions in order to increase engines efficiency and to reduce environmental polluting fumes emanated from the engine exhaust for both stationary and transportation applications. Proton exchange membrane fuel cells (PEMFCs) have recently approved on the scene and are expected to play a significant role in the next generation of energy consumption systems as a clean power source for various applications. These cells work by direct conversion of chemical energy of reaction between hydrogen and oxygen into electricity. In addition, there is several coupled fluid flow and mass transport processes that occur in a fuel cell in conjunction with the electrochemical reaction. The main advantages of PEMFCs are low operating temperature, high-energy efficiency and low environmental pollution [1]. A fuel cell provides higher energy efficiency than the internal combustion engines and there are no harmful emissions [2]. Currently, many research efforts focus on the development of more efficient PEMFC that produce high current densities for longer operational periods [3]. The effects of a poor or Mal distribution 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 [4]. In serpentine type flow fields, longer straight channels and segments between channel, bends and narrower channels enhance convective flow, improving the performance of the cell. Likewise, square channel bends provoke higher pressure drop compared to curvilinear channel bends. Serpentine and interdigitated flow fields enhance uniform reactants distribution over the catalytic layers, increasing both, the current density values and performance of the cell. [5]. Channel length and the number of channels are two of the most influential geometric parameters on the fuel cell performance, especially in serpentine flow fields. Several studies analysed the reactants convective flow under the rib [6, 7]. The reactant transport, reactant utilization and liquid water removal were enhanced in comparison with a conventional serpentine flow field as the reduction of the outlet channel flow area was greater [8].

II. MODELING

In order to design a complete model of the three pass curved serpentine flow field design different modeling parameters like flow channel height, length, width, etc. are taken into account. Complete isometric model is shown in figure.1. Mesh model of the three pass curved serpentine flow field design is shown in figure.2.

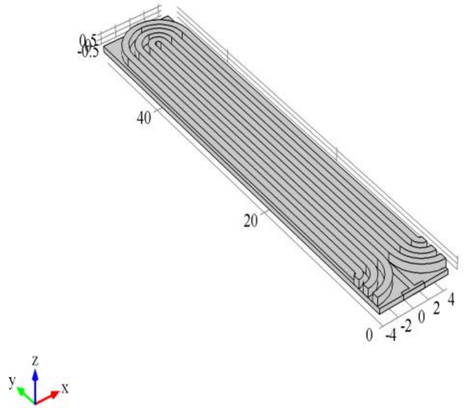

Fig.1. Isometric Model

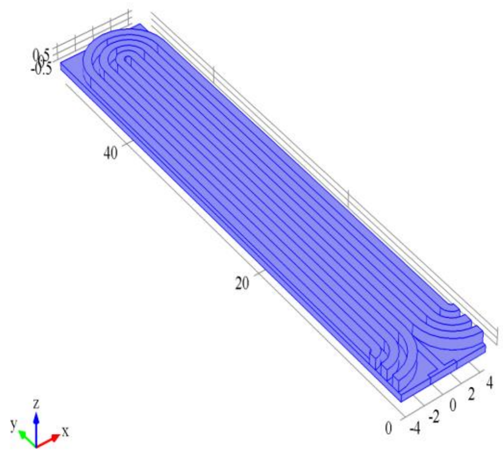

Fig.2. Mesh model

III. RESULTS & DISCUSSIONS

A. Membrane current density

Figure.3-7 shows the membrane current density of three passes curved serpentine flow field model operating at cell voltages of 0.25, 0.35, 0.45, 0.55 and 0.65 V respectively. Among these five cell voltages PEM fuel cell with 0.25 V gives the maximum membrane current density of 1.8011 A/cm^2.

B. Power density

Compared with different cell voltages, PEM fuel cell with three passes curved serpentine flow field model gives the maximum power density of 0.47619 W/cm2 at cell voltage of 0.65 V.

C. Gas diffusion layer pressure distribution

Figure.9-13 shows the gas diffusion layer pressure distribution of three passes curved serpentine flow field model operating at cell voltages of 0.25, 0.35, 0.45, 0.55 and 0.65 V respectively. There is a significant pressure difference between the up going and down going parts of the bottom channel. Among these five cell voltages PEM fuel cell with 0.25 V gives the maximum gas diffusion layer pressure distribution (353.96 Pa).

D. Gas diffusion layer velocity distribution

Figure.15-19 shows the gas diffusion layer velocity distribution of three passes curved serpentine flow field model operating at cell voltages of 0.25, 0.35, 0.45, 0.55 and 0.65 V respectively. The velocity is highest in the middle of the channels; in the gas diffusion layer the velocities are generally low. The channel velocity is lowest around the upper end of the down most channels. Among these five cell voltages PEM fuel cell with 0.25 V gives the maximum gas diffusion layer velocity distribution (0.0708 m/s).

E. Cathode oxygen concentration

Figure.21-25 shows the cathode oxygen concentration of three passes curved serpentine flow field model operating at cell voltages of 0.25, 0.35, 0.45, 0.55 and 0.65 V respectively. The oxygen concentration towards the outlet in the down most channels is higher than in the other two channels. Among these five cell voltages PEM fuel cell with 0.25 V gives the maximum cathode oxygen concentration (8.2167 mol/m3).

F. Polarization curves

Figure.27 shows the effect of change of cell voltages inside the cell for current and power densities of three passes curved serpentine flow field model of PEM fuel cell. PEM fuel cells with three passes curved serpentine flow field model gives the maximum current and power densities (1.8011 A/cm2 & 0.47615 W/cm2) at cell voltage of 0.25 V & 0.65 V respectively.

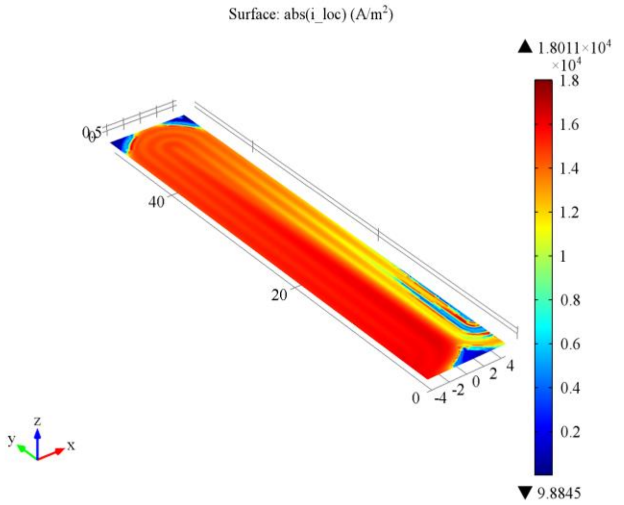

Fig.3. Membrane current density at 0.25 V

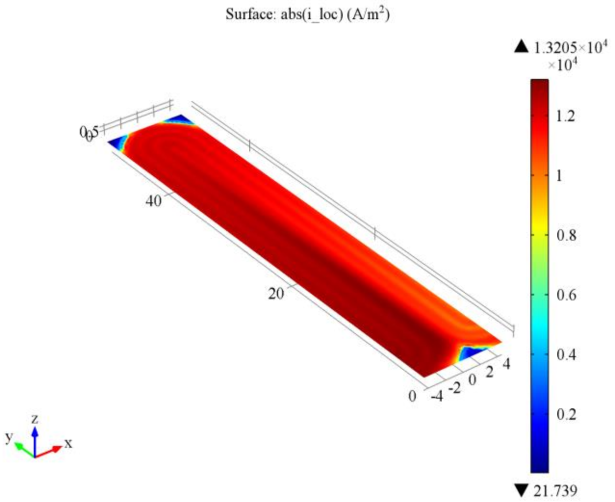

Fig.4. Membrane current density at 0.35 V

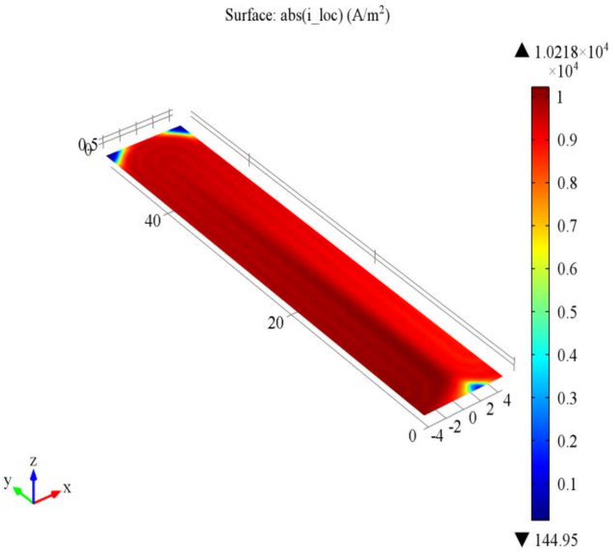

Fig.5. Membrane current density at 0.45 V

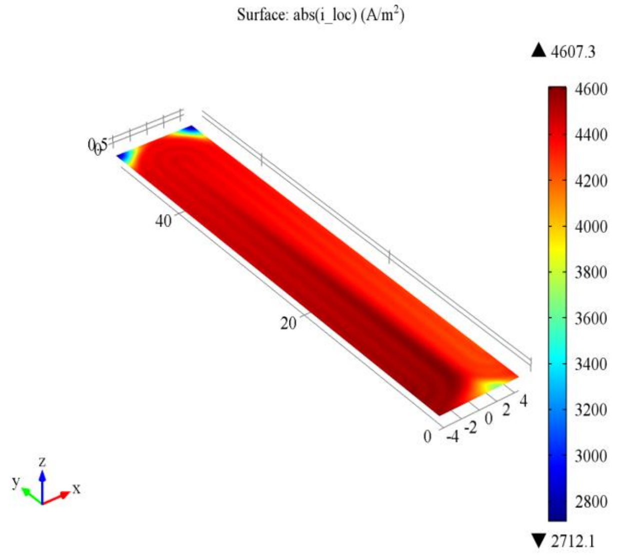

Fig.6. Membrane current density at 0.55 V

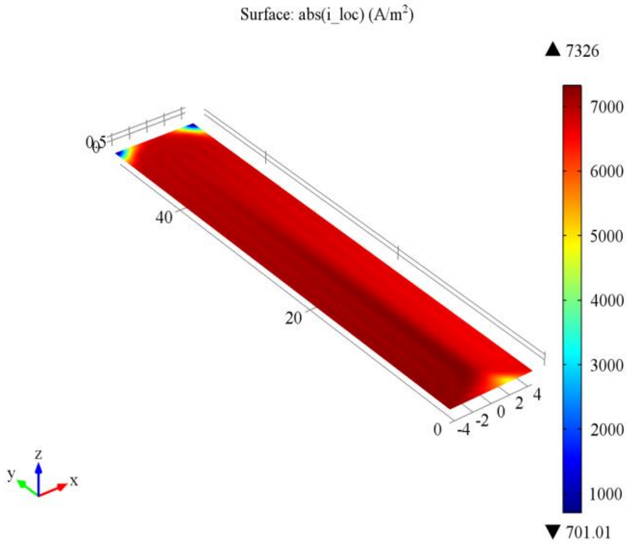

Fig.7. Membrane current density at 0.65 V

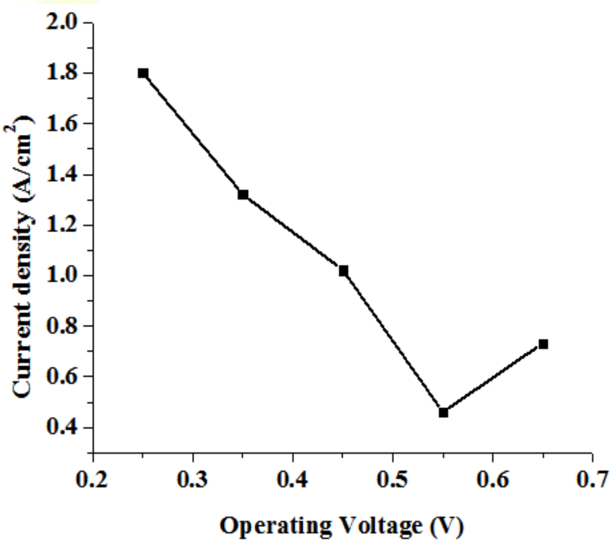

Fig.8. Membrane current density at different voltage level

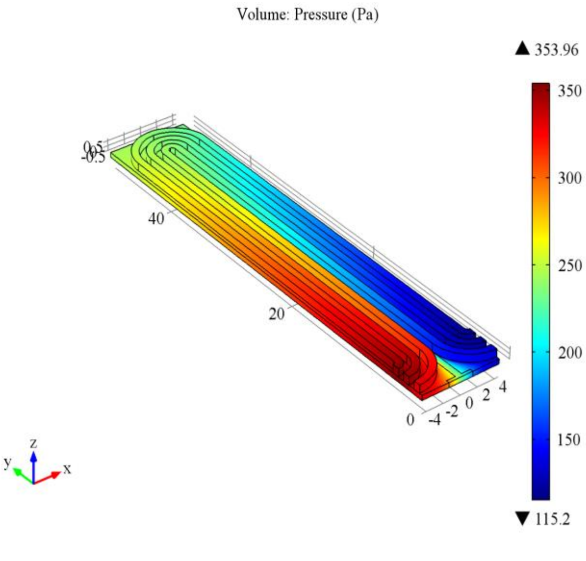

Fig.9. Gas diffusion layer pressure distribution at 0.25 V

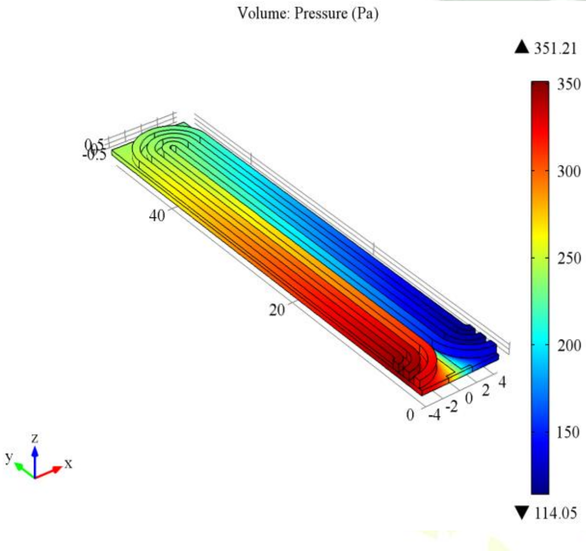

Fig.10. Gas diffusion layer pressure distribution at 0.35 V

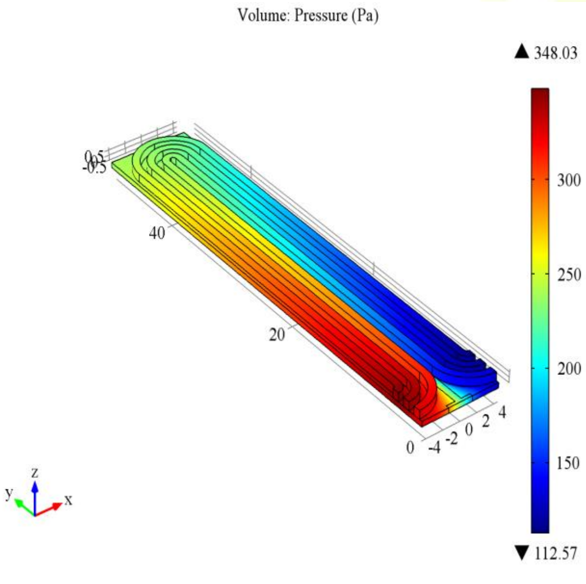

Fig.11. Gas diffusion layer pressure distribution at 0.45 V

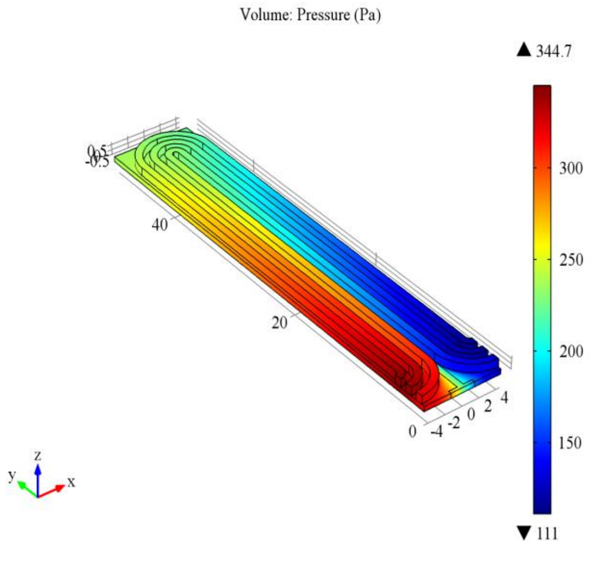

Fig.12. Gas diffusion layer pressure distribution at 0.55 V

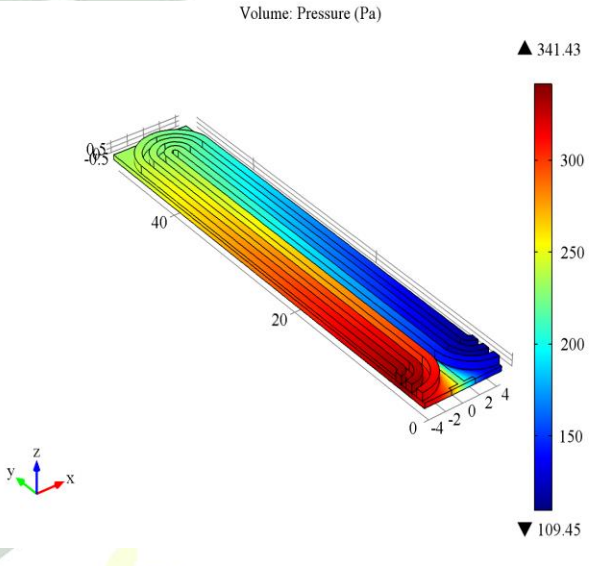

Fig.13. Gas diffusion layer pressure distribution at 0.65 V

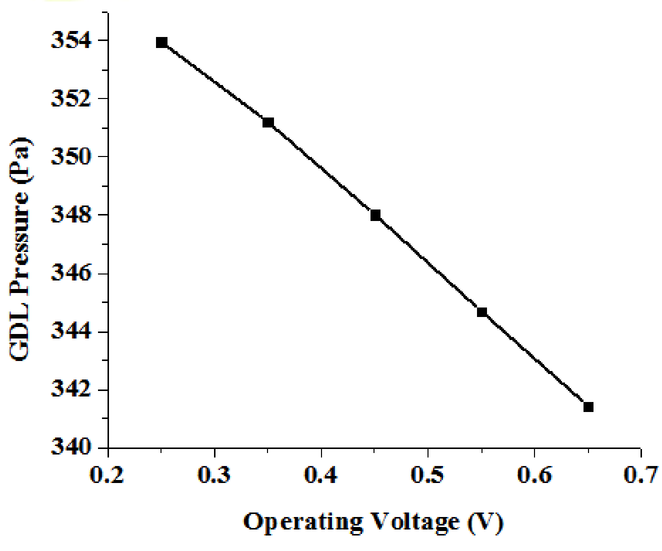

Fig.14. GDL pressure at different voltage level

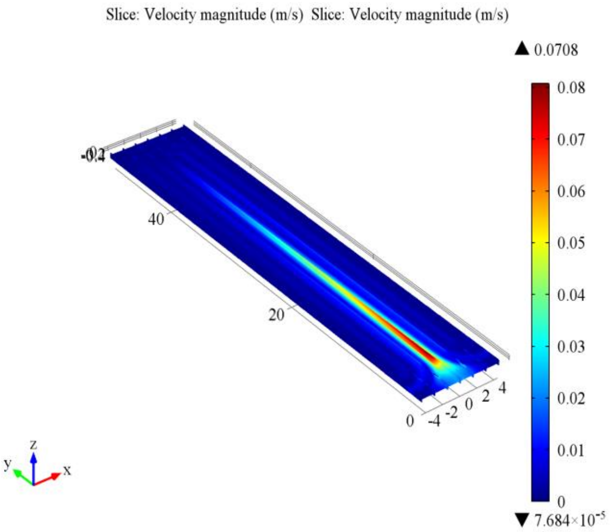

Fig.15. Gas diffusion layer velocity distribution at 0.25 V

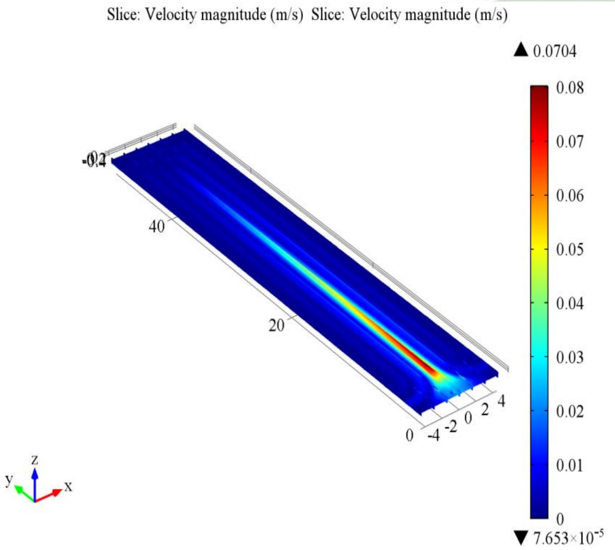

Fig.16. Gas diffusion layer velocity distribution at 0.35 V

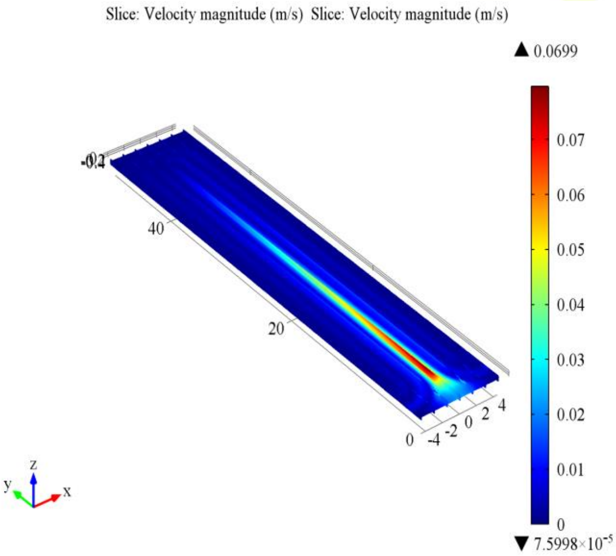

Fig.17. Gas diffusion layer velocity distribution at 0.45 V

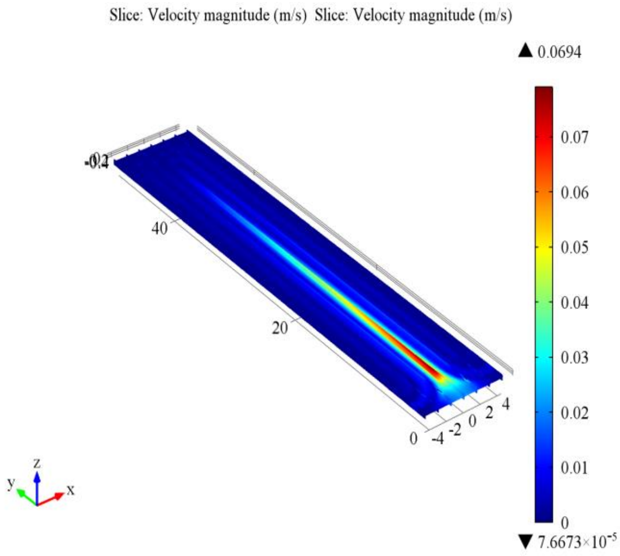

Fig.18. Gas diffusion layer velocity distribution at 0.55 V

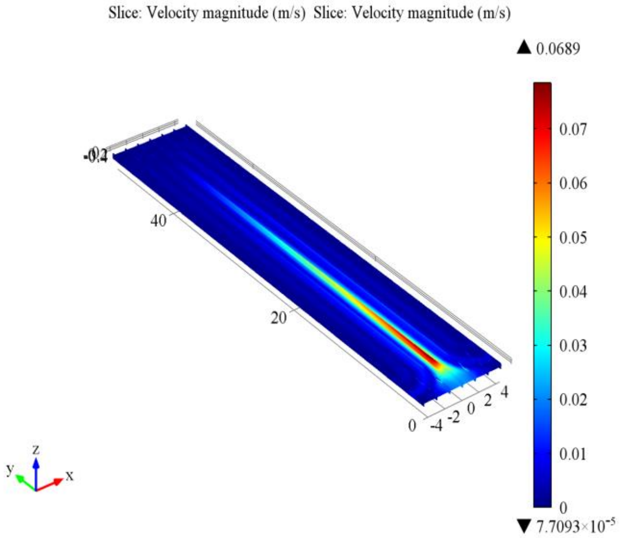

Fig.19. Gas diffusion layer velocity distribution at 0.65 V

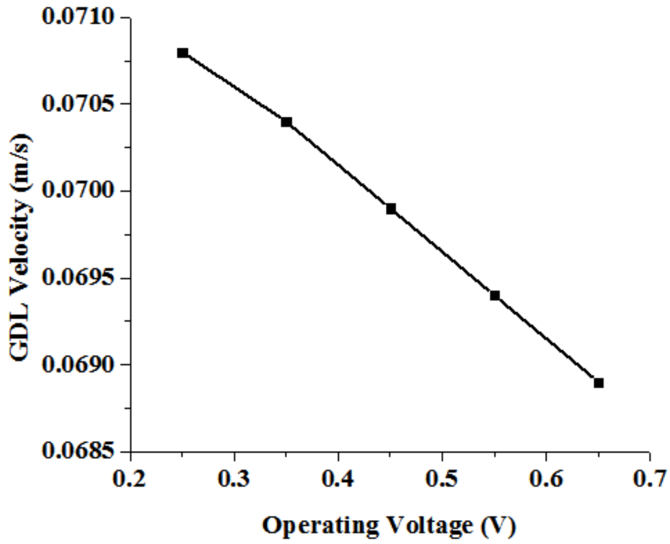

Fig.20. GDL velocity at different voltage level

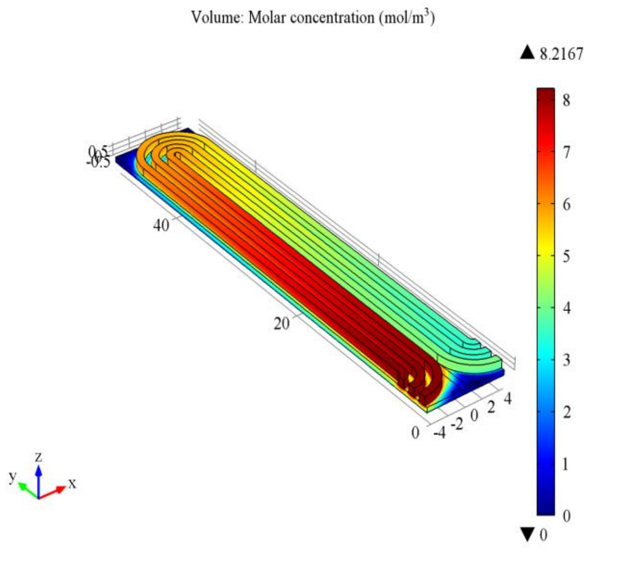

Fig.21. Cathode oxygen concentration at 0.25 V

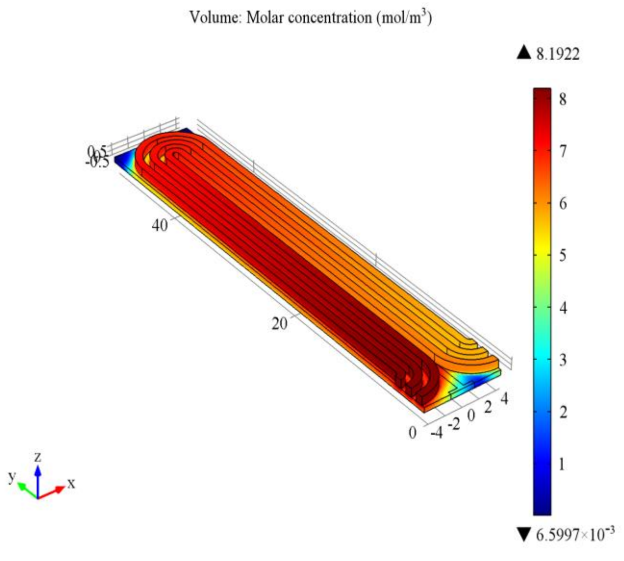

Fig.24. Cathode oxygen concentration at 0.55 V

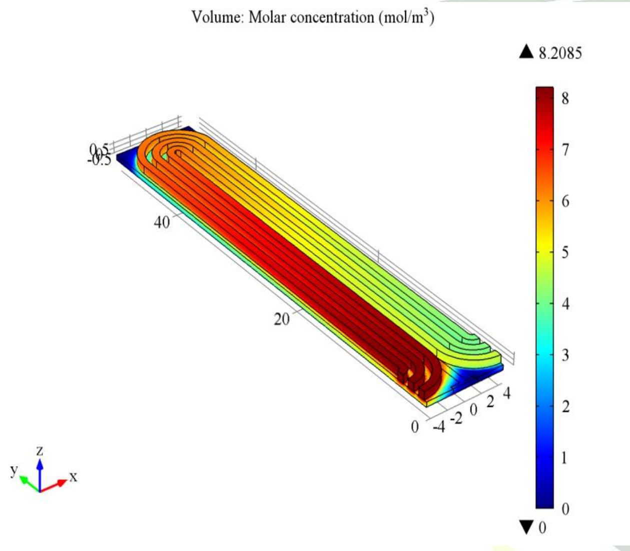

Fig.22. Cathode oxygen concentration at 0.35 V

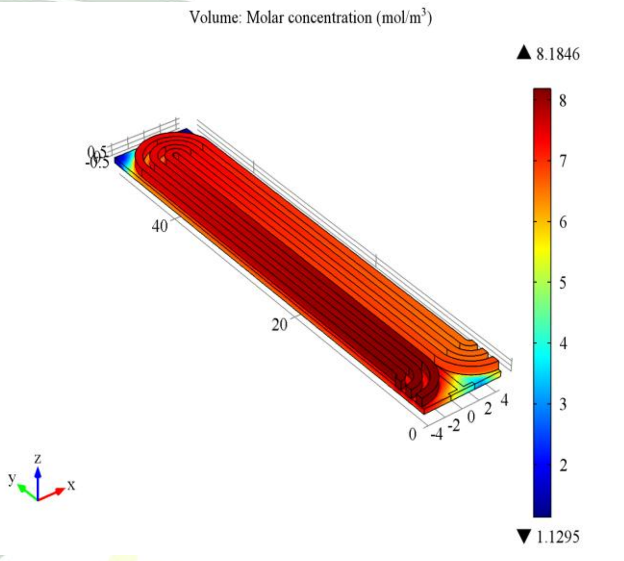

Fig.25. Cathode oxygen concentration at 0.65 V

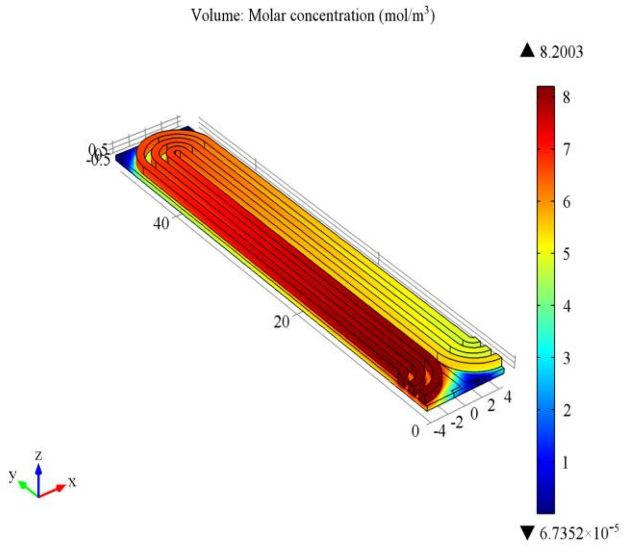

Fig.23. Cathode oxygen concentration at 0.45 V

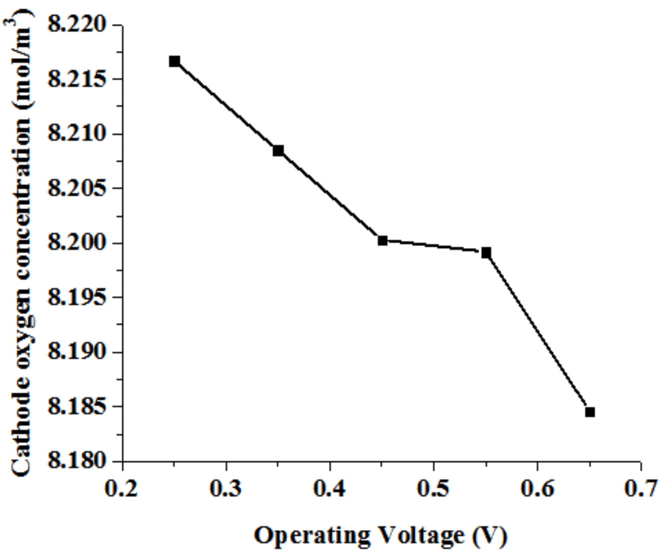

Fig.26. Cathode oxygen concentration at different voltage level

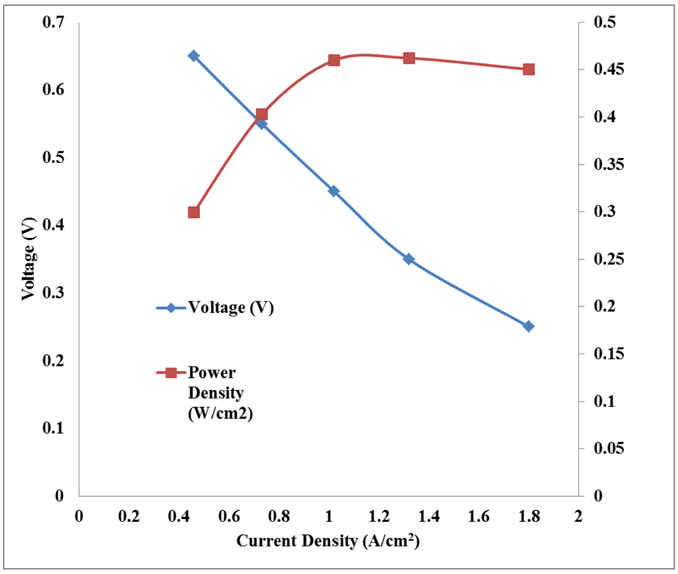

Fig.27. Polarization curve

IV. SUMMARY

In this research special configuration of PEM fuel cell with three passes curved serpentine flow field channels under different cell voltages (0.25, 0.35, 0.45, 0.55 and 0.65 V) were analysed using COMSOL 4.2 Multiphysics software. From this numerical analysis PEM fuel cell with three pass curved serpentine flow field yields maximum current density and power density at a cell voltage of 0.25V and 0.65 V respectively. Other operating parameters such as gas diffusion layer pressure, velocity distribution and cathode oxygen concentration were maximum operating at a cell voltage of 0.25 V compared with other four cell voltages.

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