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COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF FUEL CELL

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Abstract- *The* ***performance of the Proton Exchange Membrane (PEM) fuel cell has been influenced by the operating parameters. In this work comparing the performance of 81 cm²effective area with the landing to channel width ratio of (L: C) 1:1 serpentine flow channel of PEM fuel cell at various operating pressure (1 and 2 bar), temperatures ranges (303, 313, 323 and 333K) and constant mass flow rate of reactants was analyzed numerically. CATIA V5 tool and the Fluent CFD 16.0 software were used to create mode and analysis. The L: C-1:1 has produced maximum power density of 0.152 W/cm² with 2 bar pressure and operating temperature of 323 K on serpentine flow channel of PEM fuel cell****.*

Keywords— Operating parameter, CFD, CATIA, Power density, landing to channel width ratio*.*

I. INTRODUCTION

The environmental impacts of non-renewable power sources and energy scarcity in many countries, focuses on renewable energy development. The Polymer Electrolyte Membrane fuel cells are environment friendly power source which is suitable for powering both portable devices and mobile application due to their high energy density and lower operating temperature range viz, 30^{o}C - 70^{o}C [1]. The PEMFC consists of solid polymer electrolyte membrane placed between two electrodes namely cathode and anode. The performance of PEMC on serpentine single pass flow channel of 64 cm^2 active area with various design parameters with constant pressure of 2 bar and inlet reactant mass flow rate of the PEM fuel cell has been examined by Lakshminarayanan et al [2]. The results concluded that the power densities of serpentine flow channel with R:C -1:2 were found to be 0.134, 0.139 and 0.137 W / cm^2 for temperature 313, 323 and 333 K respectively. Khazaee et al. [3] examined experimentally on 25 cm^2 active area of PEMFC with various operating parameters like cell temperature, pressure, reactants on anode and cathode. He concluded that the performance of the PEMFC found with the increase in operating pressure and increase in cell temperature. Iranzo et al. [4] examined a CFD model of 50 cm^2 parallel and serpentine flow fields using the fluent software for performance progress of PEMFC. The result shows that the performance of serpentine flow field had performed better than the parallel flow field performance. The various operating parameters with Multipass serpentine flow channel PEMFC with 36 cm^2 effective area was analyzed numerically by Lakshminarayanan et al [5].The result was concluded that the maximum power densities was obtained in the L: C of 1:1. Nicholas S. Siefert [6] concluded in his study that the serpentine channels are very effective to remove the liquid because of its high gas velocity. However, Water accumulation leads the fuel cell performance unpredictable and unreliable under the nominal operating conditions. So the critical issue for PEMFC can be resolved through appropriate design of flow channels for effective removal of water built in the flow field plates. The performance of interdigitated and serpentine flow channel of PEM fuel cell with many parameters has been optimized by Taguchi method numerically. The result revealed that the interdigitated flow channel showed better performance than serpentine flow channel by Lakshminarayanan et al [7]. So identifying the proper channel and flow field design are also affecting the performance of fuel cell significantly [8]. Generally the trend is going to do the analysis of PEM fuel cell with various flow field designs and their influence using Computational Fluid Dynamics (CFD) [9]. In this study, the performance of PEMFC with Landing to Channel width of (L: C) 1:1 on Serpentine flow channel with various pressure (1and 2 bar), operating temperature (303, 313, 323 and 333 K) and constant mass flow rate of reactants was analysed numerically.

II. METHODOLOGY

The modelling of 81 cm^{2}effective area with serpentine flow channel with the landing to channel width ratio of (L: C) 1:1of PEM fuel cell involved three major steps. The first step was creating individual parts of the multi pass single channelled serpentine PEM fuel cell which was done in CATIA V5 tool. Creating the mesh from the geometry using ICEM CFD 16.0 was the second step. The simulation has been solved by all the simultaneous equations to obtain reaction kinetics of PEM fuel cell, namely mass fraction of H_2, O_2, H_2O, temperature, static pressure and current flux density distribution. Creating a good mesh has been one of the most difficult steps involved in modelling. It requires a careful balance of creating enough computational cells to capture the geometry without creating much of its mesh care should be taken such that it would not exceed the available memory of the meshing computer. Many other factors must also be considered into account in order to generate a computational mesh which provides sample results when simulated. The last step was the adoption of boundary condition with physical and operating parameters of PEM fuel cell for solving the reaction kinetics. The analysis was done by the CATIA V5 tool and the Fluent CFD 16.0 software and the Fig.1 shows the 2D model of serpentine flow channel of 81 cm^2 effective area with landing to channel ratio of various (L:C) – 1:1.

The Table1 shows the serpentine flow channel of 81 cm2 effective area of PEM fuel cell. All the inlets should be assigned the boundary zone type as ‘mass flow inlet ‘and outlets should be assigned as ‘pressure outlet’ type. The anode is grounded and the cathode terminal is at a fixed potential which is less than the open circuit potential. Both the terminals should be assigned as ‘wall’ boundary type. Voltage jump zones can optionally be placed between the gas diffusion layer and current collector. Faces which represent solid interfaces must be of the type ‘wall’.

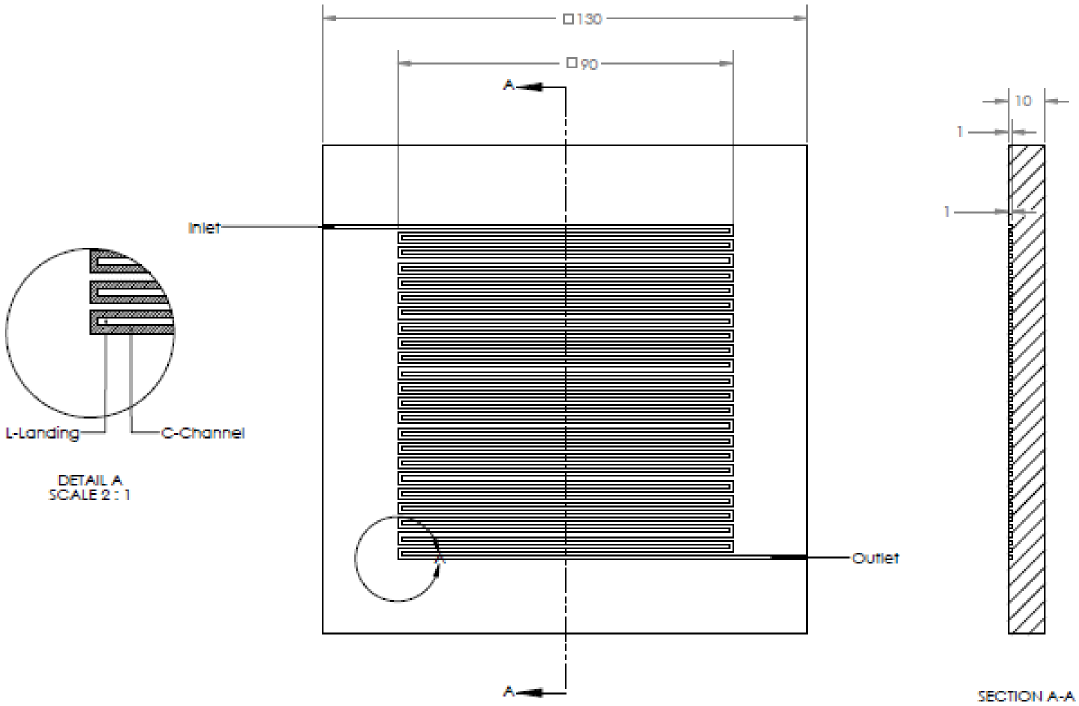

Fig. 1. 2D model of serpentine flow channel of 81 cm^2 effective area with Landing to Channel ratio (L:C) – 1:1

Table 1. DIMENSIONS OF ACTIVE AREA OF PEM FUEL CELL

S.No	Part Name	Width(mm)	Length(mm)	Thickness (mm)	Zone type
1	Catalyst - anode & cathode	90	90	0.08	Fluid
2	Current collector - anode & cathode	130	130	10	Solid
3	Membrane	90	90	0.127	Fluid
4	GDL - anode & cathode	90	90	0.3	Fluid

Boundary conditions

Inlet and outlet zones for the anode gas channel

Inlet and outlet zones for the cathode gas channel

Surfaces representing anode and cathode terminals

Optional boundary zones that could be defined include any voltage jump surfaces, interior flow surfaces or non-conformal interfaces that are required.

Continuum Zone

Flow Channels for anode and cathode-sides Anode and cathode current collectors Anode and cathode gas diffusion layers Anode and cathode catalyst layers Electrolyte membrane

III. RESULT AND DISCUSION

The current density has been taken for the serpentine flow channel with various operating temperature, pressure and constant mass flow reactant of L:C -1:1of PEM fuel cell. Fig.1. Shows the graph between the polarization and performance curve of 81 cm^2 effective area with L:C-1:1 ratio of PEM fuel cell with various temperature (303, 313, 323, 333K), 1 bar operating pressure and constant stoichiometric ratio. The L:C 1:1 of serpentine flow channel with 1 bar and various temperature ranges show the maximum current density of 0.355A/cm^2 and the power density was found to be 0.151W/cm^2 at 303K, 323K and 333K. The maximum current density of 0.355A/cm^2 and the power density was shown to be 0.151W/cm^2 followed by 0.353A/cm^2 and 0.149W/cm^2 for the 313K. The minimum current density of 0.353A/cm^2 and power density of 0.149W/cm^2 is produced at 313K for 81 cm^2 effective area of PEM fuel cell. Similarly Fig.2. Shows the graph between the V-I and P-I curve of 81 cm^2 of L: C-1:1 ratio with various temperature ranges with constant pressure of 2 bar and constant stoichiometric ratio. The maximum current density of 0.357A/cm^2 and the power density was found to be 0.152W/cm^2 for the temperature of 323 K. The maximum current density of 0.357A/cm^2 and the power density was shown to be 0.152W/cm^2 followed by 0.354A/cm^2, 0.353A/cm^2 and 0.351A/cm^2 for the temperature of 313K, 303K and 333 K. The minimum current density of 0.351A/cm^2 and power density of 0.149W/cm^2 is produced at 333 K of 81 cm^2 effective area of PEM fuel cell.

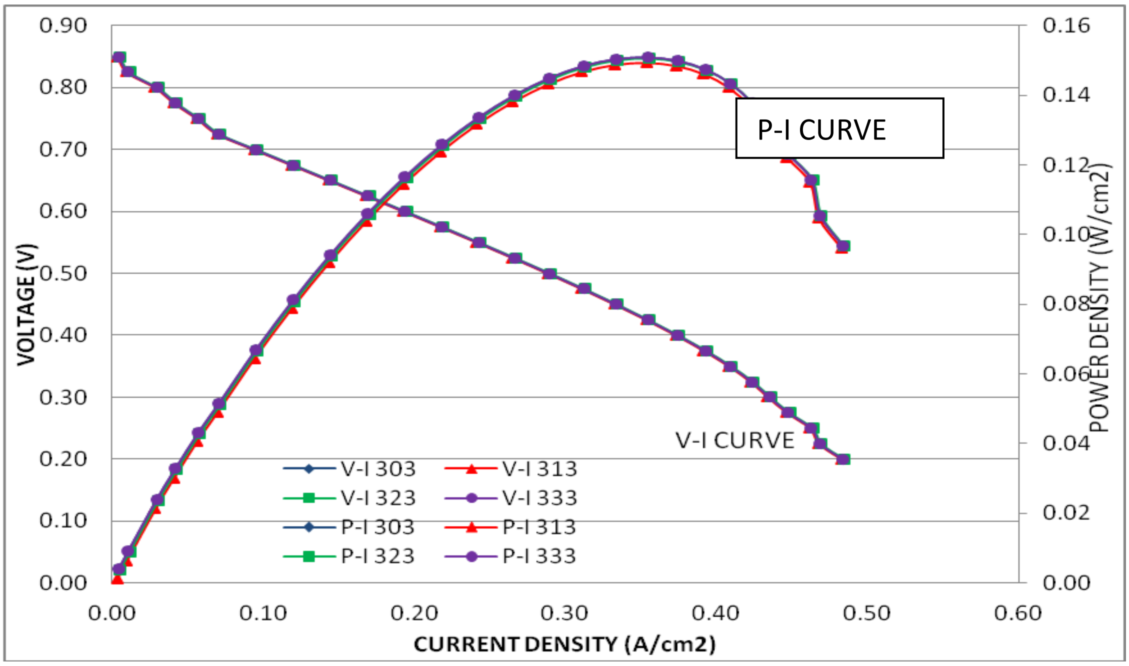

Fig. 2. Polarization and Performance curve of 81 cm^2 serpentine flow channel with various temperatures with 1 bar pressure

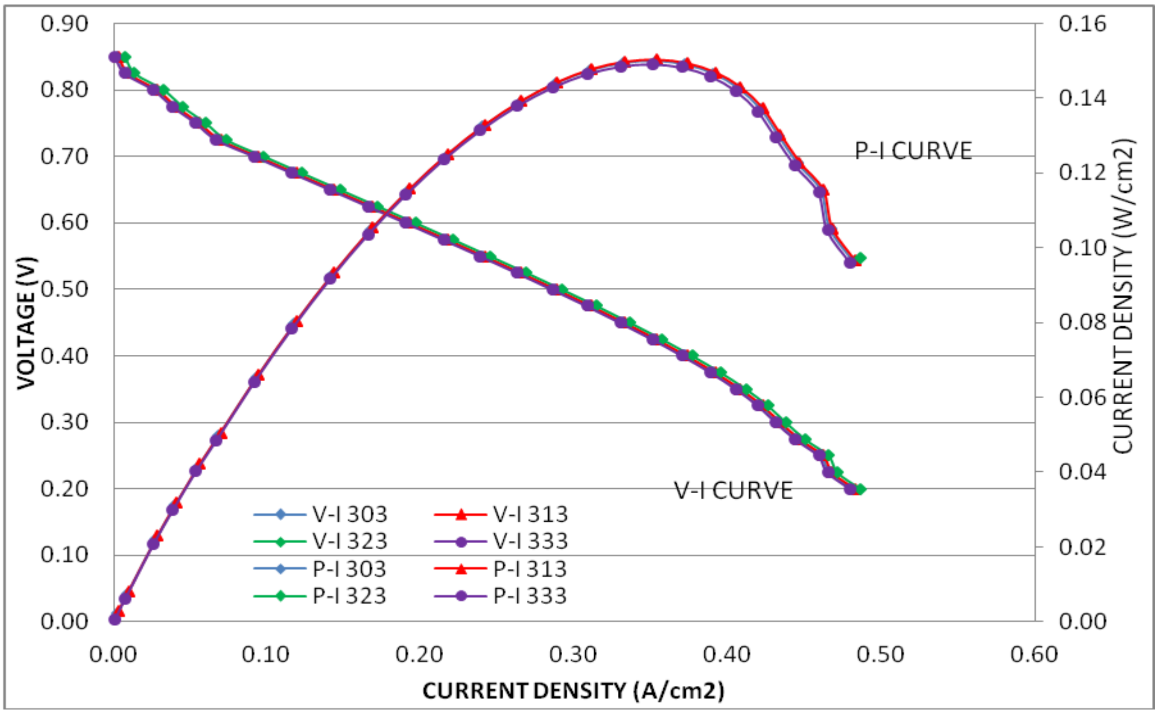

Fig. 3. Polarization and Performance curve of 81 cm^2 serpentine flow channel with various temperatures with 2 bar pressure.

Table 2. THE COMPARISON OF POWER FOR 81 CM^2 SERPENTINE FLOW CHANNEL WITH VARIOUS TEMPERATURE RANGES AND PRESSURE OF PEM FUEL CELL.

TEMPERATURE (K)	**303**		**313**		**323**		**333**	
PRESSURE (Bar)	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
CURRENT DENSITY (A/cm2)	0.355	0.353	0.353	0.354	0.355	0.357	0.355	0.351
POWER DENSITY(W/cm2)	0.151	0.150	0.149	0.150	0.151	0.152	0.151	0.149

The Table 2 showed the comparison of obtained power of L:C-1:1 from various temperature ranges (303, 313, 323 and 333 K), pressure (1 and 2 bar) and constant mass flow rate of reactants for 81 cm^2 effective area of serpentine flow channel of PEM fuel cell. Hence the PEM fuel cell with 81 cm^2 effective area, maximum power density and current density was achieved as 0.355 A/cm^2 and 0.151 W/cm^2 for 1 bar pressure at 303, 323 and 333 K respectively.

IV. CONCLUSIONS

Numerical studies on L:C- 1:1on serpentine flow field of 81 cm^2 effective area at various operating pressure (1 and 2 bar), temperature ranges (303, 313, 323 and 333K) with constant mass flow rate of reactant was analysed numerically. Based on the numerical studies, the maximum power density was achieved as 0.151W/cm^2 with 1 bar pressure for all the three temperatures (303K, 323K and 333 K) and 0.152 W/cm^2 power density with 2 bar pressure at 323 K temperature. The percentage deviation of power density was 0.657 for 81 cm^2 serpentine flow channel of PEM fuel cell.

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