Computational Fluid dynamics analysis 81cm^2 of PEMFC

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Abstract Many parameters affect the performance of the fuel cell. In this work the performance of 81 cm2active area with landing to channel width ratio (L: C) 2:1 serpentine flow channel of Proton Exchange Membrane Fuel Cell (PEMFC) for various pressure (1bar and 2 bar), various operating temperatures ranges (303,313, 323 and 333K) at constant mass flow rate of reactants was analyzed numerically. The model was developed and simulated using CATIA V5 tool and the Fluent CFD 16.0 software respectively. The L: C-2:1 has produced maximum power density of 0.151 W/cm2 at 1 bar pressure at 323 K temperature on serpentine flow channel of PEMFC.

***Keywords* — Fuel cell, Serpentine flow channel, CFD, Power density, parameters, L:C.**

I. INTRODUCTION

The PEMFC is an efficient energy converting device which converts chemical energy of the air fuel mixture into electrical energy. The environment friendly fuel cell produces electrical energy along with heat and water as byproducts as long as the reactants are feeding. The PEM Fuel Cell is promising one for automobile application due to its lower operating temperature, quick startup and its quick response to changes in power demand addressed by [1]. The PEM Fuel Cell consists of an anode and a cathode in between these a proton exchange membrane is sandwiched. Pure hydrogen as fuel is supplied at the anode and is converted into charged protons and electrons. The protons move towards the cathode side through the membrane, whereas the current passes through the outer circuit. Positively charged protons and negatively charged electrons combine at the cathode side and combine with oxygen to produce water and heat. Nguyen and White [2] and Yi and Nguyen [3] published two-dimensional models explaining the importance of thermal and water management to maintain the PEMFC performance. Though, the first model was quasi two-dimensional, and the other two models neglected the gas diffusion layers. However the effect of the ribs between the gas channels was omitted in one and two dimensional models. Dutta et al [4] developed a three dimensional model to present distributions like pressure, velocity, local current contours and mixture density under the ribs. A recent study has shown that water management is important to ensure stable operation, high efficiency and to maintain the power density of PEM fuel cells in the long run. The effect of the design and operating parameters of two pass interdigitated flow channel with 49 cm2 effective area affect the performance of the PEMFC was analyzed numerically by Lashminarayanan et al [5].The results revealed that the L:C-1:1 has produced maximum power of 12.58 watts with constant pressure and operating temperature of 333 K on multi pass interdigitated flow channel of PEMFC.The performance of PEMFC with design and various operating parameters analyzed on serpentine flow channel by Taguchi technique was done by Lakshminarayanan et al.[6] Based on the optimization study, the L: C- 1:2 have given 0.223 W/cm2 maximum power density on PEMFC performance and square of response factor (R2) was achieved as 99.69 %.The performance of PEMC on serpentine single pass flow channel of 64 cm2 active area with various landing to channel width ratio 1:1, 1:2, 2:1 and 2:2 , various operating temperature (313, 323 and 333), constant pressure of 2 bar and inlet reactant mass flow rate of the PEM fuel cell has been examined by Lakshminarayanan et al [4]. 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 / cm2 for temperature 313, 323 and 333 K respectively. So identifying the proper channel and flow field design is a very important task while designing the fuel cell which also affects 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]. Serpentine single pass flow channel has not been considered with various operating and design parameter in the above analysis. Hence, in this paper immediate attention is required on single pass serpentine 81 cm2 active area of PEM fuel cell with constant mass flow rate of species for various operation conditions like pressure(1 and 2), temperature(303, 313, 323 and 333K) and design parameter like landing to channel width ratio (L:C)- 2:1.

II. METODOLOGY

The modeling of 81 cm2 active area with serpentine flow

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channel with the landing to channel width ratio of (L: C) 2:1of PEM fuel cell involved three major steps. The first step was creating individual parts of the single channeled 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. In order to solve the myriad of equations associated with a fuel cell simulation, the entire cell was divided into computational cells. The simulation has been solved all the simultaneous equations to obtain reaction kinetics of PEM fuel cell, namely mass fraction of H2, O2, and H2O, temperature, static pressure and current flux density distribution. Creating a good mesh has been one of the most difficult steps involved in modeling. It requires a careful balance of creating enough computational cells to capture the geometry without creating much of its 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 representative 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.Fig.1 shows 2- dimensional view of 81 cm2 active area of serpentine flow channel with L:C – 2:1

Table1. Shows the active area of the serpentine flow channel of 81 cm2 active 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 (V = 0) and the cathode terminal is at a fixed potential which is less than the open circuit potential. Both the terminals should be assigned the ‘wall’ boundary type. Voltage jump zones can optionally be placed between the various components (such as between the gas diffusion layer and the current collector). Faces which represent solid interfaces must be of the type ‘wall’.

The current density has been taken for the serpentine flow channel with various operating temperature, pressure and constant mass flow reactant of L:C -2:1of PEM fuel cell. Fig.2. Shows the graph between the polarization and performance curve of 81 cm2 effective area with L:C-2:1 ratio of PEM fuel cell with various temperature (303, 313, 323, 333K), 1 bar operating pressure and constant stoichiometric ratio. The L:C 2:1 of serpentine flow channel with 1 bar and various temperature ranges show the maximum current density of 0.352 A/cm2 and the power density was found to be 0.149 W/cm2 at 303 K.

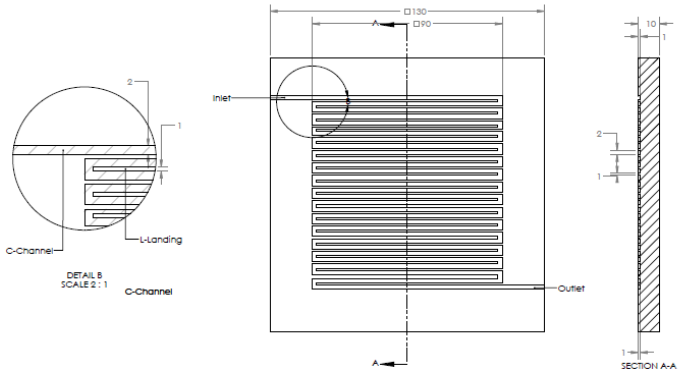

Fig. 1. 2D model of serpentine single pass flow channel of 81 cm2 active area with Landing to Channel ratio of (L:C) – 2:1

Table 1.Dimensions of 81 cm2 active area of 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

III. RESULT AND DISCUSION

Similarly the maximum current density of 0.353A/cm2 and the power density was found to be 0.150W/cm2for the 313K and 0.354 A/cm2 and the power density was found to be 0.151W/cm2 at 333 K temperature. For the temperature of 333 K, maximum current density of 0.353A/cm2 and the power density was found to be 0.149 W/cm2.The minimum current density of 0.352A/cm2 and power density of 0.149W/cm2 is produced at 303K for 81 cm2 active area of PEM fuel cell. Similarly Fig.3. Shows the graph between the V-I and P-I curve of 81 cm2 of L: C-2:1 ratio with various temperature ranges, constant pressure of 2 bar and constant stoichiometric ratio. The maximum current density of 0.353A/cm2 and the power density was found to be 0.150W/cm2 for the temperature of 303 K. The maximum current density of 0.352A/cm2 and the power density was found to be 0.149W/cm2for the temperature of 313 and 323 K. The minimum current density of 0.350A/cm2 and power density of 0.149W/cm2 is produced at 333 K of 81 cm2 active area of PEM fuel cell.

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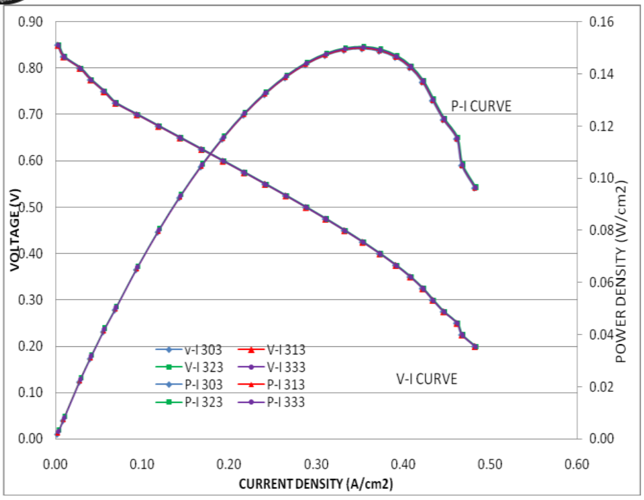

Fig. 2. Polarization and Performance curve of 81 cm2 serpentine flow channel with various temperatures with 1 bar pressure

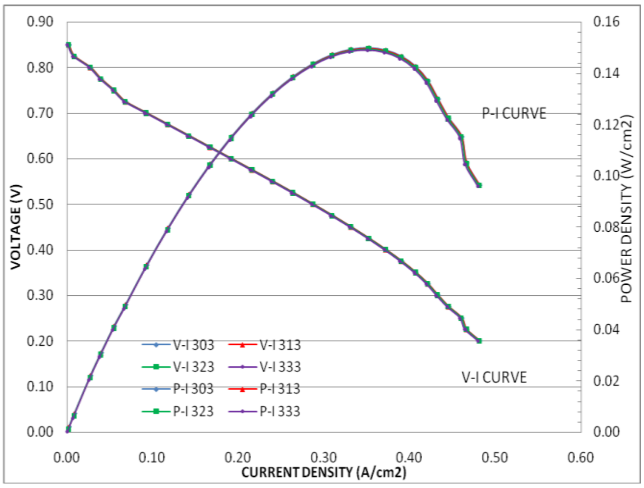

Fig. 3. Polarization and Performance curve of 81 cm2 serpentine flow channel with various temperatures with 2 bar pressure

Table 2. The comparison of power for L:C-2:1 81 cm2 serpentine flow channel with various temperature ranges of PEMFC.

TEMP. (K)	303		313		323		333	
PRES. (Bar)	1	2	1	2	1	2	1	2
CUR .DEN .(A/cm2)	0.352	0.353	0.353	0.352	0.354	0.352	0.353	0.350
POW. DEN (W/cm2)	0.149	0.150	0.150	0.149	0.151	0.149	0.150	0.149

The Table 2 showed the comparison of obtained power of L:C-2:1 from various temperature ranges, pressure and constant mass flow rate of reactants for 81 cm2 active area of serpentine flow channel of PEM fuel cell. Hence the PEM fuel cell with 81 cm2 active area at 323 K, maximum power density and current density was achieved at 1 bar pressure 0.354 A/cm2 and 0.151 W/cm2 respectively. For 2 bar pressure, maximum power density and current density was achieved as 0.353 A/cm2 and 0.150 W/cm2 respectively.

IV. CONCLUSION

Computational fluid dynamics studies on L:C- 2:1on serpentine flow field of 81 cm^2 active area at various operating pressure (1 and 2 bar), temperature ranges (303, 313, 323 and 333K) with constant mass flow rate of reactant was analyzed numerically. From the numerical studies, the maximum power density was obtained as 0.151 W/cm^2 at 1 bar pressure and 323 K temperature and 0.150 W/cm^2 power density at 2 bar pressure with 303 K temperature. The percentage deviation of power density was 0.1 of 81 cm^2 serpentine flow channel of PEM fuel cell.

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