IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Investigation of Interdigitated Flow Channel for the Performance Analysis of the PEMFC

[1]Dr V Lakshminarayanan, [2]Ajith V S, [3]John George

[1]Professor, [2,3]Assistant Professor

Department of Aeronautical Engineering,
Jawaharlal College of Engineering and Technology, Palakkad, Kerala - India.

Abstract: **The performance of fuel cell depends on the various design and operating parameters. The Proton Exchange Membrane Fuel Cell (PEMFC) performance depends on the operating like operating temperature, pressure, stoichiometric ratio of hydrogen and oxygen and design parameters like landing width to channel width ratio (L:C), the shape of the flow channel and the number of passes in the flow channel. In this work, single pass interdigitated flow channel of 16 cm^2 (4cm x 4cm) active area model has been designed using Creo software and it has been analyzed using CFD fluent software. The power density has been calculated for L:C - 2:2 with the effect of various operating temperature (303, 313,323 and 333K), constant pressure of 2 bar and constant inlet reactant mass flow rate of the PEMFC has been considered.**

Index Terms **-** PEMFC; design parameters; operating parameters; landing to channel width ratio; CFD; interdigitated flow channel.

I. INTRODUCTION

The PEMFCs are being well-known for commercial applications in the areas of transportation and back-up power due to the negligible emission of pollutants, such as SOX, NOX, particulates [1]. It is a sustainable power source suitable for powering both portable devices and mobile application due to their high energy density and lower operating temperature range [2]. The PEMFC contains of polymer solid electrolyte membrane inserted between an anode and cathode. Fuel cells are converting chemical energy of hydrogen which is fed into the anode side and oxygen in the cathode side directly into electricity without any intermediate stage. It has become an integral part of alternative energy sources with high energy efficiency without affecting the atmosphere. Among all types of fuel cells, the proton exchange membrane fuel cell has grasped important stage, particularly for mobile and portable applications [3]. The effect of the various parameters and various landing to channel width of multi pass serpentine flow channel of PEM fuel cell with 36 cm^2 effective area was analyzed numerically by Lakshminarayanan et al [4]. Santarelli & Torchio [5] discussed the characterization of the behavior of a PEMFC effective area of 25 cm^2 with various operating parameters (cell temperature, the anode and the cathode flow temperature in saturation and dry conditions, and reactant pressure). The results exhibited that the increase of temperature, reactants pressure and humidification at high cell temperature improved the performance of PEMFC. Also the performance has been improved with increased pressure along with humidification at both anode and cathode but, the increase of the operating pressure of dry reactants did not show any performance improvement. The result concluded that the maximum power densities of 0.658, W/cm^2 were obtained in the landing to channel width ratio of - 1:1 .The numerical investigation of 49 cm^2 active area of the PEMFC with various landing width to channel width of single pass serpentine flow channels with various pressure and various operating temperature was carried out by Lakshminarayanan et al [6]. The performance of PEMFC has been analyzed from the numerical study also the better landing width to channel width of the flow channel, pressure and temperature was identified. The performance improvement of the serpentine flow channel with 64 cm^2 active area of the proton exchange membrane has been studied with the effect of design parameter like various landing to channel width ratio and the operating parameters like various operating temperature, constant pressure of 2 bar and inlet reactant mass flow rate by Lakshminarayanan et al [7]. The results showed that the maximum numerical 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. 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]. It is clearly indicated that immediate attention is required for influence of operating and design parameters for the performance of the PEMFC. Hence this paper has a detailed study about the various temperature, constant operating pressure and stoichiometric ratio of inlet reactant mass flow rate with landing to channel width (L:C)- 2:2 on interdigitated flow channel of 16 cm^2 active area of PEMFC are to be studied and influence their performance are compared.

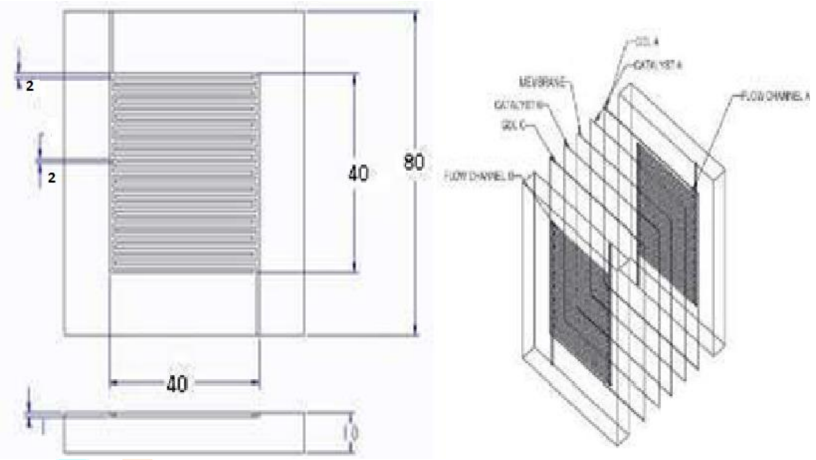

Fig. 1. Interdigitated flow channel of (a) Landing to channel width ratio - L:C - 2:2 and (b)Various parts associated with PEMFC

In this study, single pass interdigitated flow channel of 16 cm^2 (4cm x 4cm) active area with landing width to channel width ratio (L:C) - 2:2 has been created with the help of Creo software and the created modal was analyzed by Ansys CFD Fluent software. This performance of PEM fuel cell has also been found out with various operating temperature of 303K, 313K,323 K and 333 K, constant operating pressure of 2 bar and three times to the theoretical inlet reactant mass flow rate at the anode and cathode side.

II. NUMERICAL ANALYSIS OF PEM FUEL CELL:

The modeling of various landing to channel width ratio 2:2 with interdigitated flow channel of 16 cm^2 active area of PEM fuel cell as shown in the Fig. 1(a) and the corresponding dimensions have been mentioned in Table 1.

Table 1. Dimensions of interdigitated fuel cell of 16 cm^2 active area

Elements	Length(cm)	Width(cm)	Thickness(cm)
MEA Assembly	4	4	0. 0127
Gas Diffusion Layer	4	4	0.03
Flow Channel	4	4	0. 1
Anode Plate	4	4	1
Cathode Plate	4	4	1

The development of interdigitated flow channel of 16 cm^2 of PEMFC model has been involved three major steps. The first step was creating geometry modeling of the fuel cell using Creo Parametric 2.0. The modeling was done by creating individual parts such as anode, cathode, catalyst, gas diffusion layer and membrane as shown in the Fig. 1 (b). The second step involved, creating the mesh from the geometry using ICEM CFD 14.5. The third and final step involves adoption of boundary condition with physical and operating parameters of PEMFC for solving the above mentioned reaction kinetics. The Continuum and boundary condition of interdigitated flow channel as shown in the table 2.

Table 2. Continuum and boundary condition of interdigitated flow channel of 16 cm^2 active area

Continuum Zone	**Boundary Conditions**
Flow Channels for anode and cathode sides	Inlet and outlet zones for the anode gas channel
Anode and cathode current collectors	Inlet and outlet zones for the cathode gas channel
Anode and cathode gas diffusion layers	Surfaces representing anode and cathode terminals
Anode and cathode catalyst layers	Optional boundary zones that could be defined include any voltage jump surfaces, interior flow surfaces or non-conformal interfaces that are required.

In order to solve the myriad of equations associated with a fuel cell simulation, the entire cell was divided into a finite number of discrete volume elements or computational cells. The simulation has been solved simultaneous equations like conservation of mass, momentum, energy, species, Butler–Volmer equation, Joule heating reaction and the Nernst equation to obtain reaction kinetics of PEM fuel cell, namely mass fraction of H_2, O_2, and H_2O, temperature, static pressure and current flux density distribution. 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'.

III. RESULTS AND DISCUSSION:

The performance of the PEMFC with L:C - 2:2 interdigitated flow channel and operating parameters has been shown by performance curve (P-I curve) and polarization curve (V-I curve). The obtained power density of interdigitated flow channel with constant pressure and various operating temperature for landing to channel width ratio 2:2 was to be 0. 318 W/cm^2 and the corresponding current density was 0.579 A/cm^2 respectively at 313 K. similarly for 303K,323K and 333 K the power density was found to be 0.314 W/cm^2, 0.312 W/cm^2 and 0.311 W/cm^2 and the corresponding current density of 2:2 was 0.571 A/cm^2, 0.594 A/cm^2 and 0.565 A/cm^2 respectively. The performance (P-I) and polarization (V-I) curve of L:C 2:2, constant pressure and various temperatures have been shown in the Fig. 2. The current density and power density of L:C 2:2 for various temperature with constant stoichiometric ratio and constant pressure of 2 bar has been mentioned in table.3.

Table.3. The current density and power density of L:C 2:2 for various temperature with constant pressure and stoichiometric of PEMFC.

VOLTAGE	303 K		313 K		323 K		333 K	
	A/cm^2	W/cm^2	A/cm^2	W/cm^2	A/cm2	W/cm2	A/cm2	W/cm2
0.875	0.101	0.088	0.119	0.104	0.085	0.074	0.079	0.069
0.85	0.136	0.116	0.144	0.122	0.109	0.093	0.115	0.098
0.825	0.172	0.142	0.18	0.149	0.146	0.120	0.15	0.124
0.8	0.212	0.170	0.22	0.176	0.196	0.157	0.181	0.145
0.775	0.25	0.194	0.258	0.200	0.244	0.189	0.208	0.161
0.75	0.277	0.208	0.285	0.214	0.261	0.196	0.256	0.192
0.725	0.324	0.235	0.332	0.241	0.306	0.222	0.291	0.211
0.7	0.36	0.252	0.368	0.258	0.344	0.241	0.349	0.244
0.675	0.383	0.259	0.391	0.264	0.387	0.261	0.371	0.250
0.65	0.418	0.272	0.426	0.277	0.412	0.268	0.407	0.265
0.625	0.453	0.283	0.461	0.288	0.446	0.279	0.441	0.276
0.6	0.503	0.302	0.511	0.307	0.497	0.298	0.492	0.295
0.575	0.537	0.309	0.545	0.313	0.531	0.305	0.526	0.302
0.55	0.571	0.314	0.579	0.318	0.565	0.311	0.56	0.308
0.525	0.585	0.307	0.603	0.317	0.582	0.306	0.594	0.312
0.5	0.617	0.309	0.635	0.318	0.621	0.311	0.625	0.313
0.475	0.67	0.318	0.667	0.317	0.653	0.310	0.658	0.313
0.45	0.68	0.306	0.688	0.310	0.674	0.303	0.689	0.310
0.425	0.712	0.303	0.72	0.306	0.706	0.300	0.711	0.302
0.4	0.743	0.297	0.751	0.300	0.737	0.295	0.742	0.297
0.375	0.774	0.290	0.782	0.293	0.768	0.288	0.763	0.286
0.35	0.804	0.281	0.812	0.284	0.798	0.279	0.793	0.278
0.325	0.835	0.271	0.843	0.274	0.829	0.269	0.824	0.268
0.3	0.865	0.260	0.873	0.262	0.859	0.258	0.854	0.256
0.275	0.895	0.246	0.903	0.248	0.889	0.244	0.884	0.243

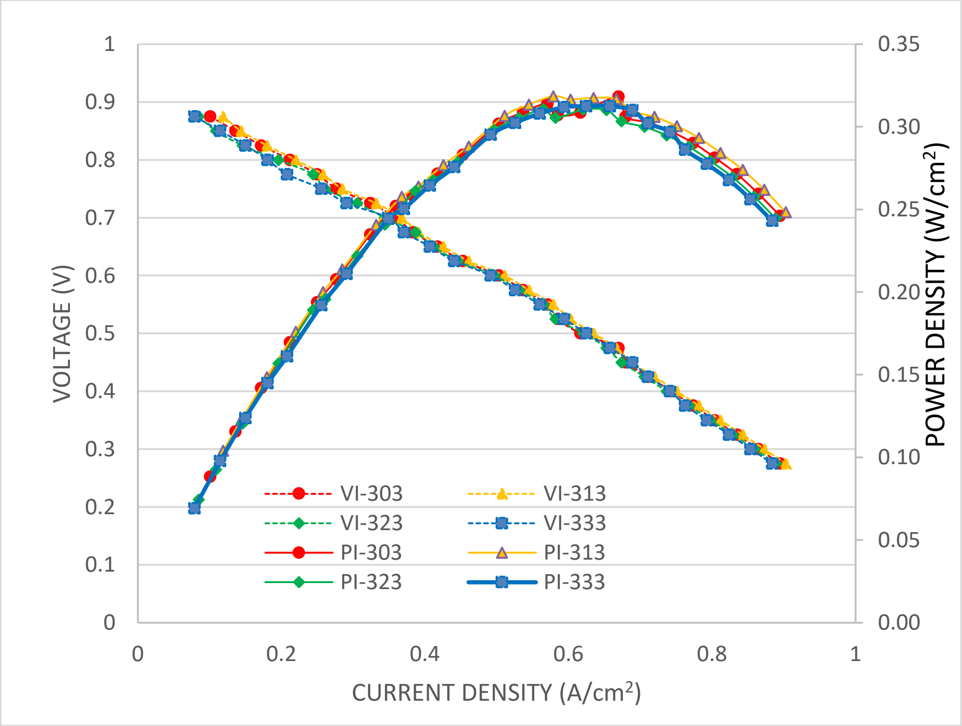

Fig. 2. P-I and V-I curve of L:C 2:2 of interdigitated flow channel with 16 cm^2 active area

This design has converted the transport of the gaseous reactant to/from the catalyst layers from a diffusion mechanism to a convection mechanism at the interface of catalyst and GDL. Convection having much faster than diffusion, the reaction rates at the catalyst sites could be significantly enhanced.

IV. CONCLUSION:

The maximum power density 0.318 W/cm^2 and current density of 0.579 A/cm^2 at 0.475 V was achieved in landing to channel width ratio of 2:2 with 16 cm^2 active area of interdigitated flow channel at constant operating pressure of 2 bar and 313 K temperature. The maximum power density of a PEM fuel cell is achieved between 0.5 - 0.6 cell potential for various operating temperatures, constant pressure and constant flow of stoichiometric ratio.

V. REFERENCES

[1] Nicholas, S.; Siefert.; Shawn Litster. (2011). Voltage loss and fluctuation in proton exchange membrane fuel cells: The role of cathode channel plurality and air stoichiometric ratio, Journal of Power Sources, 196, 1948–1954.

[2] Manso, A. P.; Garikano, X.; GarmendiaMujika, M. (2012). Influence of geometric parameters of the flow fields on the performance of a PEM fuel cell, A review International Journal of Hydrogen Energy, 37, 15256-15287.

[3] Yun Wang, Suman Basu, Chao-Yang Wang. Modeling two-phase flow in PEM fuel cell channels, Journal of Power Sources. 2008; 179, 603–617.

[4] Lakshminarayanan V, Karthikeyan P, Kiran Kumar D S and Dhilip Kumar S M K, Numerical analysis on 36cm2 PEM fuel cell for performance enhancement, ARPN Journal of Engineering and Applied Sciences, 2016; Vol. 11, no. 2.

[5] Santarelli, M & Torchio, M, “Experimental analysis of the effects of the operating variables on the performance of a single PEMFC', Energy Conversion and Management, vol. 48, no. 1, pp. 40-51, 2007.

[6] Lakshminarayanan. V, Karthikeyan. P, Mallikarjun. T, Mahesh. D, Parametric analysis of 49 cm2 serpentine flow channel of Polymer Electrolyte Membrane Fuel Cell (PEMFC) for Performance Enhancement, International Journal of Applied Engineering Research, 2015; Vol. 10 No. 85.

[7] V. Lakshminarayanan, Leo Daniel A, Numerical analysis on 64 cm2 serpentine flow channel design of PEM fuel cell, International Journal of Engineering Science and Technology, 2017; Vol. 9, 205-210.

[8] AtillaBıyıkoglu. Review of proton exchange membrane fuel cell models, International Journal of Hydrogen Energy,2005, 30, 1181 – 1212.