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Scaling up study of PEM fuel cell for performance enhancement

Scaling up performance of PEMFC

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Abstract— The Proton Electrolyte Membrane Fuel Cell (PEMFC) performance would affect the effect various design and operating parameters. In this paper, scaling up the various active area such that 9 cm^2 , 16 cm^2 and 25 cm^2 with the various landing to channel width ratio of (L: C) 1:1, 1:2 , 2:1 and 2:2 interdigitated multipass flow channel of PEMFC at pressure (1 bar) , temperature (313K) and constant mass flow rate of reactants was analyzed numerically. The model was developed and simulated using Creo 2.0 and the Fluent CFD 16.0 software respectively. The maximum power of 2.61, 4.93 and 8.52 watts were attained by scaling up study of 9 cm^2 , 16 cm^2 and 25 cm^2 active area respectively.

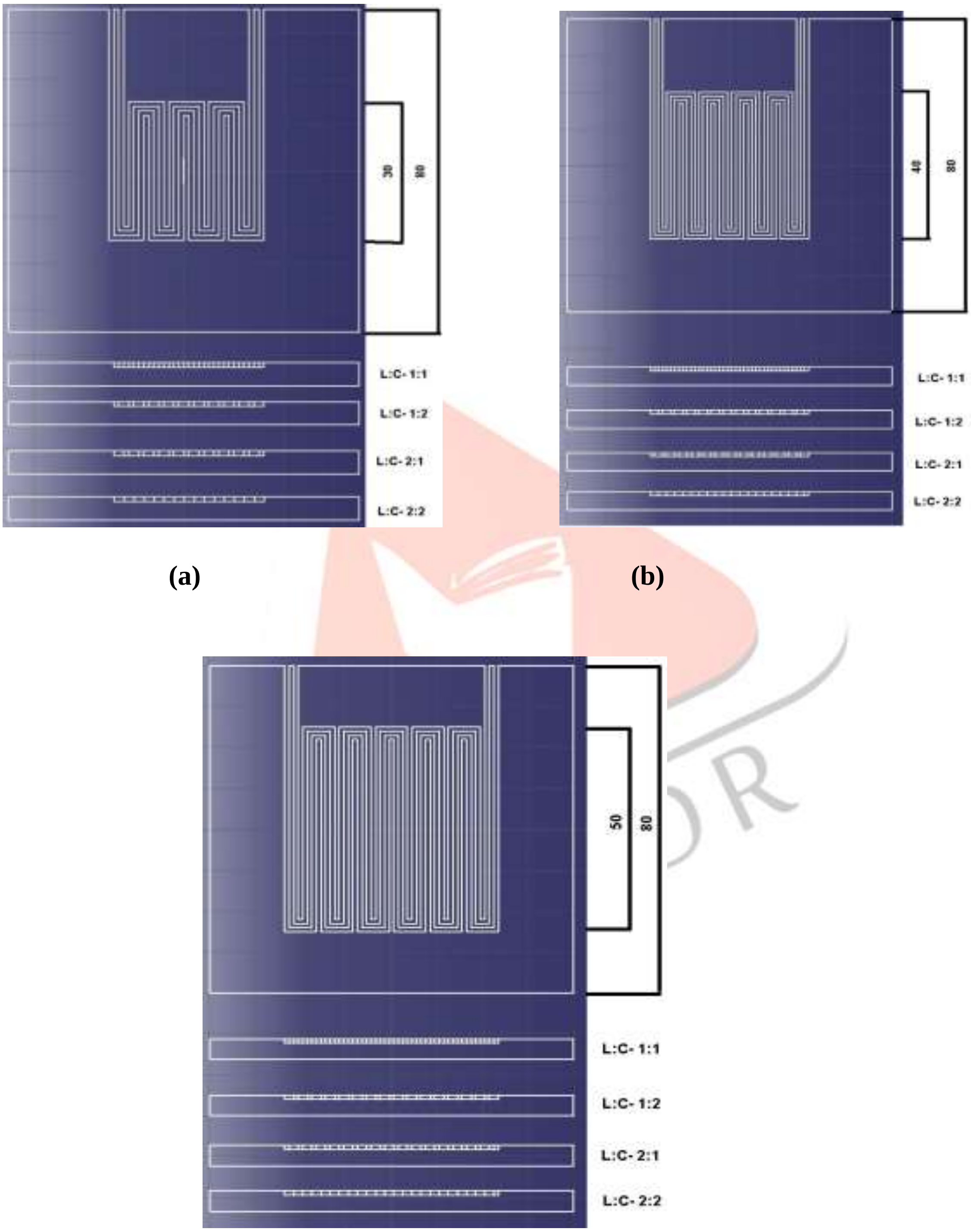
Keywords: Creo; interdigitated flow channel; PEMFC, Scaling up; CFD; Power.

I. INTRODUCTION

The energy scarcity and environmental impacts of non-renewable power sources in many countries, focusing on renewable energy source development. The proton exchange fuel cells are environment friendly power source and are suitable for powering both portable devices and mobile application due to its lower operating temperature and high energy density [1]. Khazaee et al. [2] 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 amended with the increase in operating pressure and increase in cell temperature. Manso et al. [3] studied the performance of PEMFC by various geometric parameters of the flow fields (pin type channels, integrated and interdigitated channels, straight and serpentine channels). The numerical investigation of the performance of PEMFC with various flow field designs, namely, the single parallel, serpentine, interdigitated and the pin flow field have been considered by Lee et al. [4]. The results exposed that the single serpentine flow field exhibited the best performance characteristics to the interdigitated flow field design. Yan et al.[5]. Experimentally studied the effects of interdigitated flow channel with traditional flow channel for the performance of PEMFC. The results concluded that, the cell performance can be improved with an increased inlet flow rate of reactant and cathode humidification temperature. The interdigitated flow channel has better performance than conventional flow channel design. Vazifeshenas et al. [6] examined the compound flow field design along with serpentine and parallel designs were tested by using CFD software. The results revealed that the parallel flow field revealed weaker performance in comparison to the other two flow fields. The main reason is due to insufficient distribution of the reactants. Iranzo et al. [7] examined a CFD model of 50 cm^2 parallel and serpentine flow fields using the fluent software for performance progress of PEMFC. The result determined that the serpentine flow field performed better than the parallel flow field performance. Scholta et al. [8] considered the effect of landing to channel widths on 100 cm^2 PEMFC with parallel and counter flow channel. They concluded that channel width and landing width for performance improvement of PEMFC. Hence, narrow and wider dimensions of flow channels have been better for high current density. Li et al. [9] has considered the various flow channels of active areas and decided that a serpentine channel could provide an excellent cell performance. Experimental investigation on scaling up on PEMFC performance has been completed by Karthikeyan et al. [10]. The PEMFC performance with various flow channel designs for an active area of 25 cm^2 and 70 cm^2 was considered. It was decided that, scaling up of PEMFC caused reduction in performance, since the amount of water formed on a larger scale requisite an enhanced flow distribution of the flow channel for overcoming the effect of flooding.In this study, comparing the performance of various active area such that 9 cm^2 , 16 cm^2 and 25 cm^2 of interdigitated multipass flow channel with the various landing to channel width of (L: C) 1:1, 1:2 , 2:1 and 2:2 of PEMFC at a constant pressure , temperature and mass flow rate of reactants was analyzed numerically.

II. METHODOLOGY

The modelling of 9 cm^2 , 16 cm^2 and 25 cm^2 on interdigitated multipass flow channel with the various landing to channel width ratio of (L: C) 1:1, 1:2 , 2:1 and 2:2 of PEMFC involved three major steps. The first step was creating individual parts of the multi pass channeled interdigitated PEMFC which was done in Creo Parametric 2.0. Creating the mesh from the geometry using ICEM CFD 14 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 PEMFC, namely mass fraction of H_2, O_2, and H_2O, 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 PEMFC for solving the reaction kinetics.



(a) **(b)**

(c)

Fig. 1. 2D model of interdigitated multipass flow channel of (a) $9cm^2$ (b) $16cm^2$ and (c) $25cm^2$ active area with Landing to Channel ratio of various (L:C) – 1:1, 1:2, 2:1 and 2:2

Table 1. Dimensions of various active area of PEMFC

Elements	9cm^2	16cm^2	25 cm^2	9cm^2	16cm^2	25 cm^2	Thickness (cm)
	Length (cm)			Width (cm)			
MEA Assembly	8	8	8	8	8	8	0.012
Gas Diffusion Layer	8	8	8	8	8	8	0.03
Flow Channel	3	4	5	3	4	5	1
Anode Catalyst	8	8	8	8	8	8	0.008
Cathode Catalyst	8	8	8	8	8	8	0.008

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

Tha Table 1. Shows the various active area of the multipass interdigitated flow channel of PEMFC. 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. RESULT AND DISCUSSION

The influence of various multipass flow channel design of PEMFC has been carried out by using Fluent software by constant operating pressure of 1 bar and operating temperature of 313K . The performance of the PEMFC with the above mentioned multipass flow channel and operating parameters has been shown by polarization curve (V-I curve) and the performance curve (P-I curve). The Polarization curve is the curve against the voltage (V) and current density (W/cm^2) and the performance curve is the curve against the current density (A/cm^2) and the power density (W/cm^2) which gives information about the performance of fuel cell.

Fig.1. Shows the graph between the polarization and performance curve of 25 cm^2 effective area with various L:C ratio of PEMFC at constant operating pressure(1 bar), temperature(313 K) and stoichiometric ratio. The L:C 1:2 shows the maximum current density of 0.682 A/cm^2 and the power density was found out to be 0.289 W/cm^2. The L:C 2:2 showed the maximum current density of 0.672 A/cm^2 and the power density was found out to be 0.286 W/cm^2 followed by L:C-1:1 having 0.641 A/cm^2 and 0.262 W/cm^2. The minimum current density of 0.675 A/cm^2 and power density of 0.236 W/cm^2 is produced by L:C-2: 1of 25 cm^2 PEMFC.

Similarly Fig.2. Shows the graph between the V-I and P-I curve of 16 cm^2 of various L:C ratios of PEMFC. The L:C 1:2 shows the maximum current density of 0.685 A/cm^2 and the power density was found out to be 0.308 W/cm^2. The L:C 2:2 showed the maximum current density of 0.676 A/cm^2 and the power density was found out to be 0.304 W/cm^2 followed by L:C-1:1 having 0.647 A/cm^2 and 0.291 W/cm^2. The minimum current density of 0.630 A/cm^2 and power density of 0.252 W/cm^2 is produced by L:C-2:1of 16 cm^2 PEMFC.

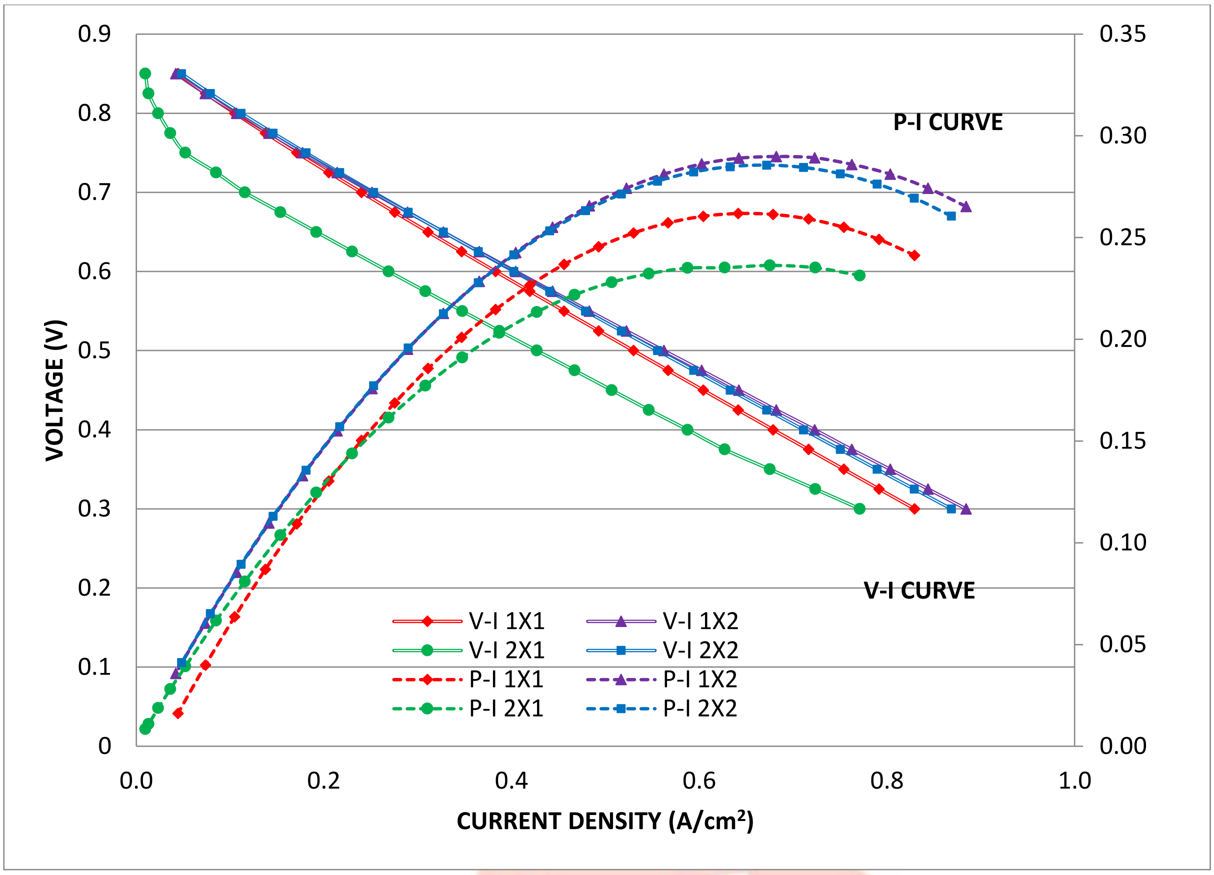


Fig. 1. Polarization and Performance curve of 9 cm^2 interdigitated multipass flow channel of PEMFC

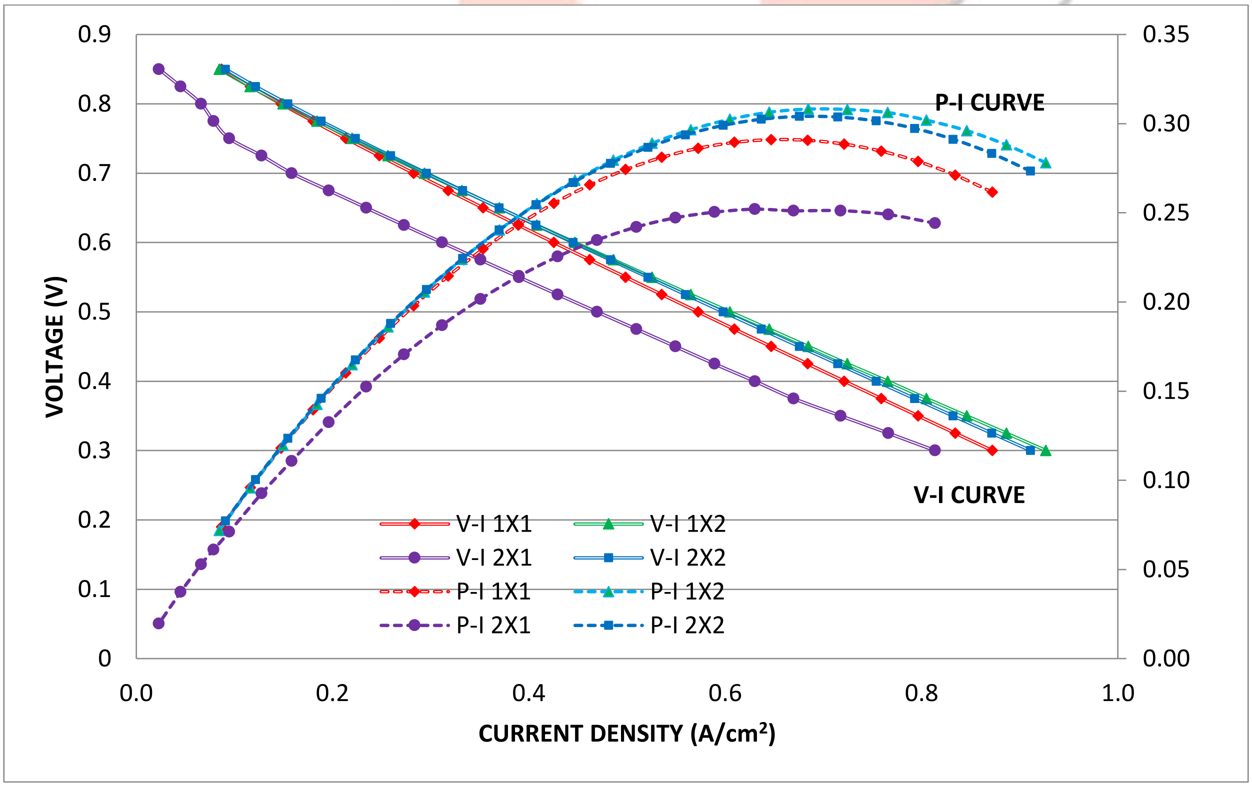


Fig. 2. Polarization and Performance curve of 16 cm^2 interdigitated multipass flow channel of PEMFC

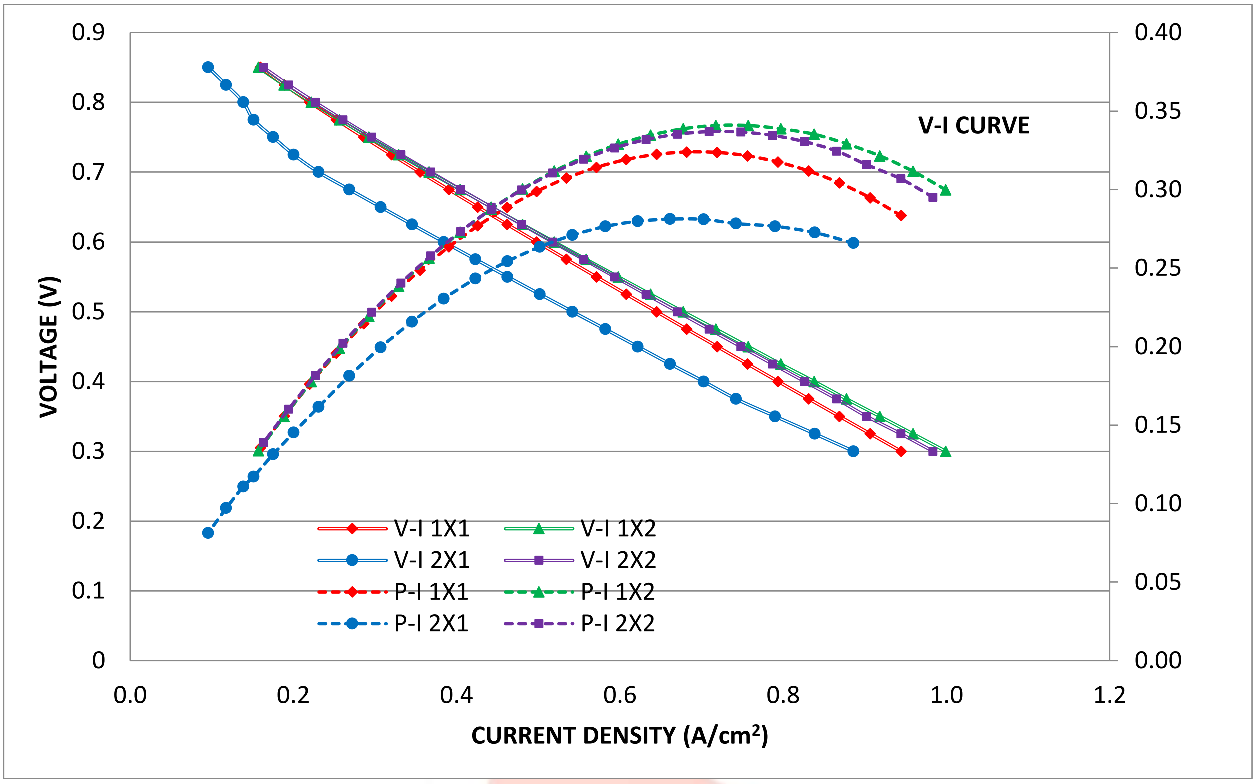


Fig. 3. Polarization and Performance curve of 25 cm^2 interdigitated multipass flow channel of PEMFC

Finally Fig.3. Shows the graph between the polarization and performance curve of 25 cm^2 effective area with various L:C ratio of PEMFC at constant operating pressure(1 bar), temperature(313 K) and stoichiometric ratio. The L:C 1:2 shows the maximum current density of 0.718 A/cm^2 and the power density was found out to be 0.341 W/cm^2. The L:C 2:2 showed the maximum current density of 0.709 A/cm^2 and the power density was found out to be 0.337 W/cm^2 followed by L:C-1:1 having 0.682 A/cm^2 and 0.324 W/cm^2. The minimum current density of 0.662 A/cm^2 and power density of 0.281 W/cm^2 is produced by L:C-2:1of 25 cm^2 PEMFC.

The Table 2 showed the comparision of obtained power from various L:C of 9 cm^2 , 16 cm^2 and 25 cm^2 active area of multipass interdigitated flow channel of PEMFC. The power has been obtained by multiplying power density with the corresponding active area of the fuel cell. Hence the PEMFC with 9 cm^2 active area, maximum power was achieved 2.61watt for the L:C 1:2 followed by 2.57, 2.36and 2.13 watts for corresponding L:C of 2:2,1:1 and L:C 2:1 respectively. The 16 cm2 active area, maximum power 4.93 watt was achieved for the L:C 1:2 followed by 4.86, 4.66and 4.03 watts for corresponding L:C 2:2,1:1 and L:C 2:1 respectively. Finally the 25 cm^2 active area, maximum power was achieved 8.52watt for the L:C of 1:2 followed by 8.42, 8.09 and 7.03 watts for corresponding L:C 2:2, 1:1 and L:C 2:1 respectively.

Table 2. Power comparision of various L:C and active area of interdigitated multipass flow channel

L:C	9 cm^2			16 cm^2			25 cm^2		
	(A/cm^2)	(W/cm^2)	Watt	(A/cm^2)	(W/cm^2)	Watt	(A/cm^2)	(W/cm^2)	Watt
1x1	0.641	0.262	2.36	0.647	0.291	4.66	0.682	0.324	8.09
1x2	0.682	0.289	2.61	0.685	0.308	4.93	0.718	0.341	8.52
2x1	0.675	0.236	2.13	0.630	0.252	4.03	0.662	0.281	7.03
2x2	0.672	0.286	2.57	0.676	0.304	4.86	0.709	0.337	8.42

The comparision of various active area of multipass interdigitated flow channel with the various L: C of 1:1, 1:2 , 2:1 and 2:2 and constant pressure , temperature and mass flow rate of reactants of PEMFC, the maximum power was achived with L:C of 1:2 as 2.61, 4.93and 8.52 watts for 9 cm^2 , 16 cm^2 and 25 cm^2 respectively.

IV. CONCLUSION

The comparision of various active area such as 9 cm^2, 16 cm^2 and 25 cm^2 of PEMFC, the maximum power was achieved 8.52 watt for L:C 1:2 of 25 cm2 effective area of PEMFC with constant operating temperatures, pressures and constant mass flow rate of reactants.

Amoung the various L:C ratio, L:C-1:2 has the predominant effect in the performance of the PEMFC followed by L:C of 2:2,1:1 and 2:1.

The power has been increased by increasing the active area of the PEMFC.

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