Performance of Proton Exchange Membrane Fuel Cell with Flow Field Designs – Review

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Abstract— The Proton Exchange Membrane Fuel Cell (PEMFC) uses a polymer membrane as the electrolyte instead of a liquid. This type of cell is very light and the solid membrane makes fabrication of the cell easier. The performance of the PEMFC is affected by design and operating parameters. In this project, the performance of the PEMFC is improved with a novel flow field. The flow field is a thin layer of the metal plate in which the gas flows into the cell. In fuel cells, the flow field plates are designed to provide an adequate amount of the reactants (hydrogen and oxygen) to the Gas Diffusion Layer (GDL) and catalyst surface while minimizing pressure drop. The most popular channel configurations for PEMFCs are serpentine, parallel, and interdigitated flow. The objective of this work is to investigate and analyze the design of the flow field.

Keywords: channel design, flow field, fuel cells, PEMFC

I. Introduction

A. *Fuel Cell*

Proton-exchange Membrane Fuel Cells, also known as polymer electrolyte membrane (PEM) fuel cells, are a type of fuel cell being developed mainly for transport applications, as well as for stationary and portable applications. The proton exchange membrane fuel cell (PEMFC) converts chemical energy into electrical energy and water. A PEMFC comprises anodic and cathodic regions and a polymer membrane electrolyte. Accurate dynamic models for the PEMFC electrical behavior allow the development of efficient controllers for a quick load-following response ensuring fuel economy and enhanced PEMFC lifetime. The flow field plays an important role in the performance and durability of PEMFCs since it helps to transport the reactants to the CL and reduces the liquid water accumulation in the CL. In this fuel cell, the flow field is the main component in which the H2 and O2 are mixed to generate power inside the cell. The flow field contains many channels arranged in a small membrane that covers the GDL on both sides of the cell. The structure of PEMFC is shown in Fig.1.

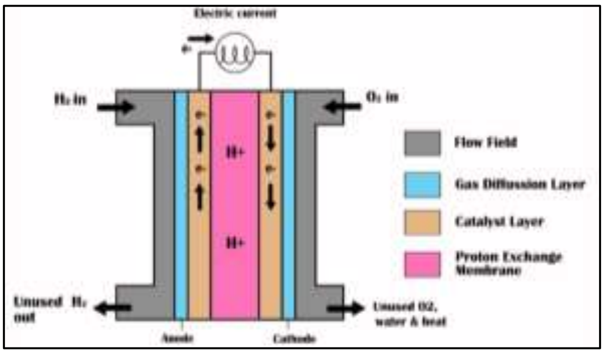


Fig.1: Structure of PEMFC

At anode CL :

$H_2 \rightarrow 2H^+ + 2e^-$ (1)

At cathode CL :

$2H+ + 2e- + ½ O2 \rightarrow H2O + Heat$ (2)

Overall reaction

$H_2 + ½ O_2 \rightarrow H_2O + Electricity + Heat$ (3)

B. *Role of the flow field in PEMFC*

The heart of the PEMFC is the Membrane Electrode Assembly (MEA). This is composed of a proton-conducting polymeric membrane (PEM) sandwiched between anode and cathode CLs (CL) as well as Gas Diffusion Layers (GDL). The flow field is the main component of the PEMFC in which the H2 and O2 are mixed to generate power inside the cell. The main function of the flow field is to supply the required amount of oxygen and hydrogen to the CL and GDL with minimum pressure drop on both sides. The flow field has channel and rib configurations to control the flow of gas.

C. *Designs in the flow field*

The flow field of PEMFC has several designs namely straight, parallel, serpentine, integrated, pin, spiral, radial, and so on. The design of the flow field is highly affecting the performance of PEMFC which leads to many modifications to improve its performance further. The designs of flow field are shown in Fig.2.

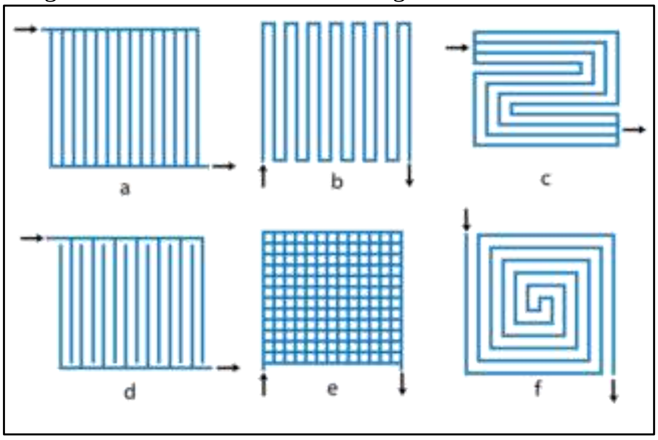


Fig. 2(a) Parallel flow field, (b) Serpentine flow field, (c) Multi-pass channel of serpentine flow field, (d) Interdigitated flow field, (e) Pin-type flow field, (f) Spiral flow field

II. Literature Survey

Hadi Heidary et al. [1] discovered that, the blockage in the flow-field channel diverts the flow into the GDL and improves mass transfer, which in turn improves the efficiency of the cell. They came up with the theories of partial blockage (Fig.3(b)) and complete blockage

(Fig.3(c)). They cut off a fraction of the flow channel for partial blockage. When in full blockage, the flow channel is completely blocked, the only way left for the continuation of the gas is to cross the blocks through the porous region (GDL). They performed a 3D numerical model consisting of a 9-layer PEMFC. Their results show that the case of full blockage enhances the net electrical power more than that of the partial blockage, with higher pressure drop.

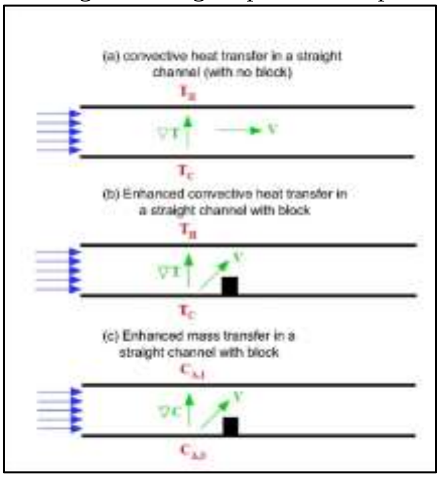
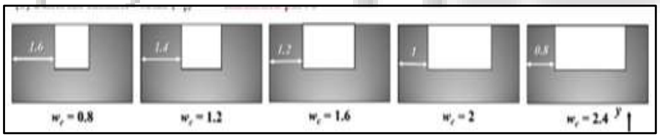
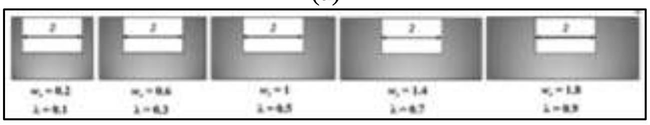


Fig. 3 (a) Straight channel with no block, (b) Partially blocked channel, (c) Fully blocked channel [1]

Weitong Pan et al. [2] used the resistances in series method to clarify the transport-reaction interactions between the layers. So, they decided to change the dimensions of channel width (as shown in Fig.4 (a)&(b)) They thought reconciliation of mass transfer area and coefficient is the key to get better performance. From the experiments, they obtained the optimal solution of channel width, based on transport capability.



(a)



(b)

Fig. 4: (a) Different channel widths- simulation-1, (b) Different channel widths- simulation-2 [2]

M. Muthukumar et al. [3] conducted numerical investigations on the effects of the serpentine flow field with different number of passes. They modeled and analyzed 2 pass, 3 pass and 4 pass serpentine flow field designs of same rib size and channel size. From the numerical results they draw polarization curves and performance curves. They compared the performance of three flow channel designs and they found maximum power densities of each design.

M. Muthukumar et al. [4] developed a full three-dimensional model of a PEMFC with a constant channel length of 20 mm and with different Landing to Channel width (LxC) in mm of 0.5x0.5, 1x1, 1.5x1.5, 2x2. They found that the PEMFC with landing to channel width of 0.5x0.5 mm yields high current density and high-power density when compared to other three designs. They also found that the smaller width of landing and channels is required for high current density and power density outputs of the PEMFC. Fig. 5 represents the different views of channel.

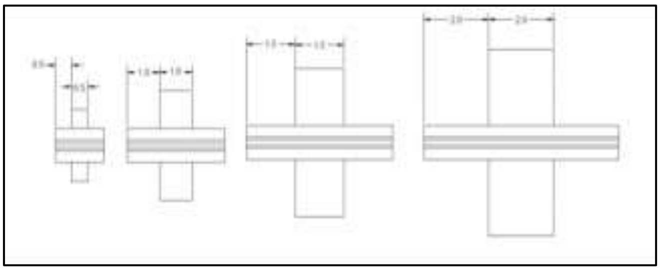


Fig. 5: Front view of PEMFC with four different Landing to Channel width [4]

M. Muthukumar et al. [5] conducted several investigations for six different cross-sections of the channel, namely square, triangle, parallelogram 14o, parallelogram 26o, trapezium and inverted trapezium of 1.25 cm2 active area with a constant cross-sectional area of 0.01 cm2 of single pass PEMFC. They developed a model and simulated under various pressures and temperature with a constant mass flow rate by using fluent CFD. They investigated the influence of the single pass flow channel on the performance of PEMFC.

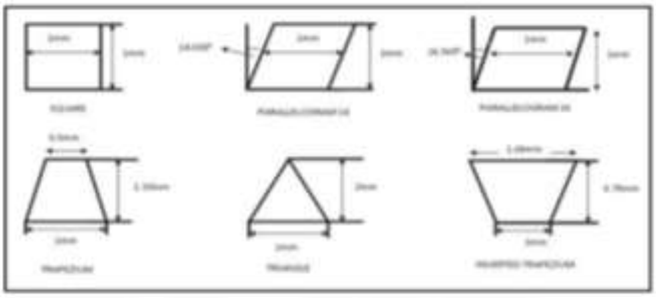


Fig. 6: Cross sections used in the single pass flow channel [5]

A. *Serpentine flow field*

Younghua Cai et al. [6] presented a novel 3D cathode flow field with main and sub-channels (as shown in Fig.7). They considered that evaluation criteria are suitable for the guidance of flow field design. They concluded that a PEMFC with the 3D cathode flow field performs much better than a PEMFC with conventional parallel straight cathode flow fields. Porous ribs on the bottom helps to improve the performance of the 3D cathode flow field.

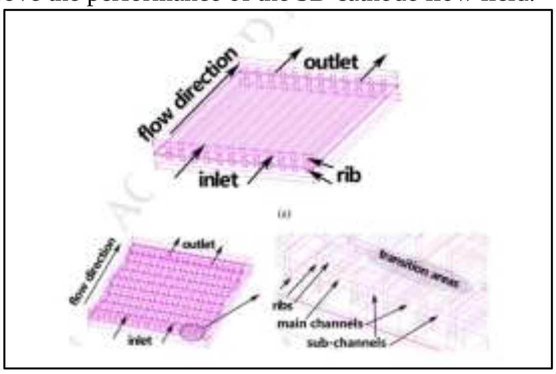


Fig. 7: 3D cathode flow field with main and sub-channels [6]

Ebrahim Afshari, et al. [7] described the concerns with numerical modelling of fluid flow through a zigzag-shaped channel which can be used as the cooling plate for PEMFC. They conducted a three- dimensional numerical simulation to obtain heat transfer rate in cooling plates. In terms of maximum surface temperature, temperature uniformity and pressure loss, they assessed the efficiency of zigzag flow channels (Fig-11 (b)). Their experiments show that, maximum surface temperature, differential, and temperature uniformity index decrease around 5 percent, 23 percent, and 8 percent respectively in the zigzag channels model. They concluded that the cooling efficiency of fuel cells can be enhanced by implementing the concept of zigzag channels as the distributors of coolant fluid.

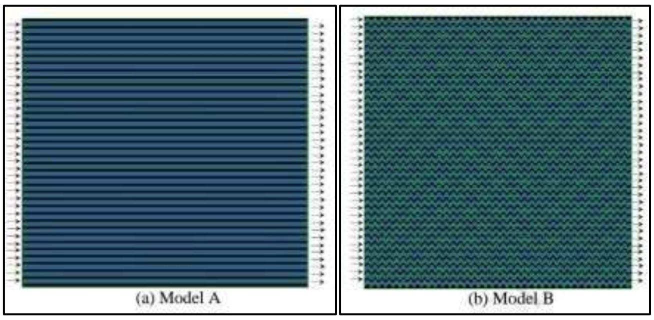
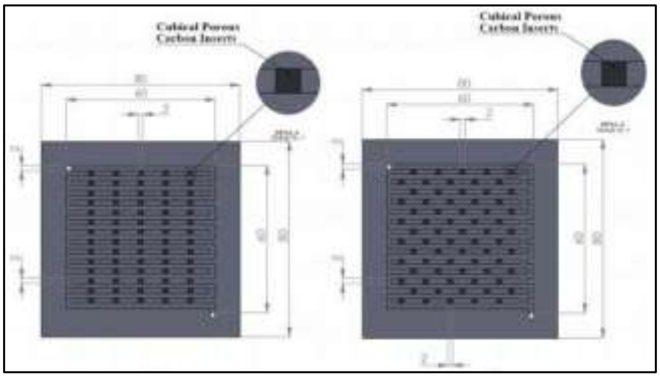


Fig.8 (a) Straight channels, (b) Zigzag channel [7]

Muthukumar Marappan et al. [8] determined water accumulation in between the GDL and cathode flow field landing in PEMFC can be removed by fixing porous inserts along the landing area of the cathode flow field. In this paper, they conducted numerical experiments on the optimum active area of the PEMFC. They evaluated the flow fields with active areas of 25 cm2, 36 cm2 and 70 cm2. They analysed all three active areas of PEMFCs with three different flow fields viz. Serpentine; Uniform and Stagger patterned pin types having porous inserts on cathode side. Their experimental results shows that the stagger patterned pin type having porous insert gained more power density than others. They identified that PEMFC with active area of 36 cm2 yields higher power density when compared to 25 cm2 and 70 cm2 PEMFCs. They concluded that the flow field with the active area of 36 cm2 is optimum active area of single cell PEMFC for performance.



(a) (b)

Fig. 9: Flow field designs of 36 cm2 active area (a) Uniform patterned pin type with porous inserts, (b) Stagger patterned pin type with porous inserts. [8]

Muthukumar Marappan et al. [9] compared PEMFC with various flow filed designs of 25 cm^2 and 70 cm^2. They also studied about the scaling up process on PEMFC with adoption of porous carbon inserts. They used serpentine channel for the experiment. They inserted the porous materials into serpentine channel in two ways. Fig.10 (a) represents uniform pin type design and Fig.10 (b) represents zigzag pin type flow field. They compared the performance of PEMFC with and without porous carbon inserts. The experimental results showed that by eliminating the water stagnant regions at the rib surface of cathode flow channel.

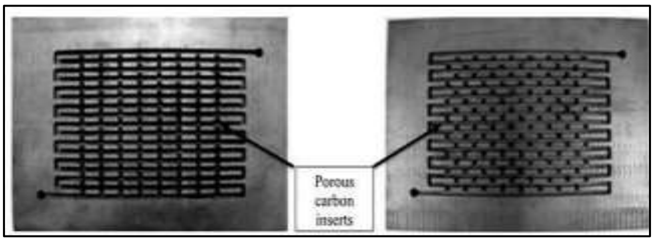


Fig. 10: Adoption of porous carbon inserts on the PEMFC with active area of 70cm^2 in (a) Uniform pin type flow field, (b) Zigzag pin type flow field. [9]

Linlin Zhang & Zhonghua Shi [10] explained the effects of GDL porosity, inlet speed, temperature, length, width, and depth on the performance of PEMFC with serpentine flow field through mathematical modelling and statistical analysis. They optimized the combination of structural and external parameters. Their research shows that the best channel pattern is an 8-channel complex serpentine flow channel with a width-depth combination of 1.2 mm wide and 0.8 mm deep. GDL porosity is the primary factor influencing water distribution, current density distribution, and oxygen distribution in SFF PEMFCs as compared to inlet speed and temperature.

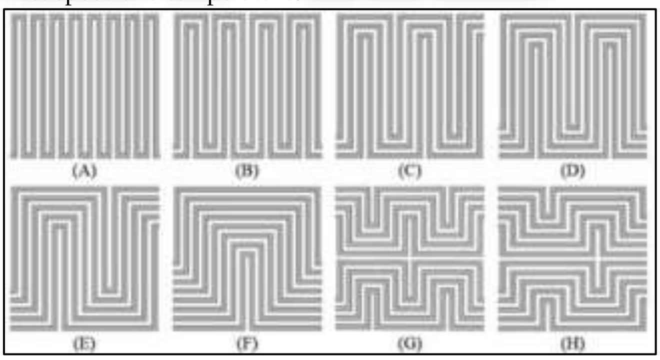


Fig.11: (a) Single channel, (b) 2 channels, (c) 3 channels, (d) 4 channels, (e) 5 channels, (f) 8 channels (g) Modified serpentine flow field with 4 channels, (h) Modified serpentine flow field with 5 channels [10]

Hanzhang Yan et al. [11] proposed a modified serpentine channel with gradient channel depth and trapezoidal section shape is proposed (Fig.12(a)). The new flow field and the traditional serpentine flow field (Fig.12(b)) are compared numerically. The numerical results reveal that when compared with the traditional flow field, the new flow field have more uniform concentration of reactants, and the water generation in the reflection area is lower due to the high channel pressure. Due to this condition, the cell's performance is increased by 23%.

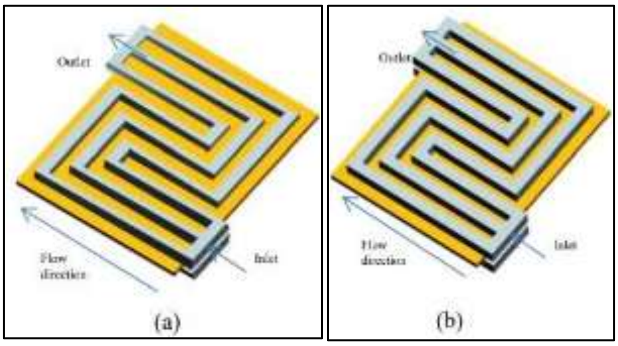


Fig. 12: (a) Modified serpentine flow field, (b) Serpentine flow field [11]

Jinhua Dong et al. [12] introduced a new kind of flow field plate structure based upon the principle of bio-inspiration and Murray's law. They did a numerical simulation to determine performance. So, they compared the contour plot, between the bio-inspired and parallel flow fields of the PEMFC. They also compared pressure and temperature distributions of the flow fields. With the experimental results, they concluded that the novel flow field plate structure (Bio-Inspired) improves the uniformity of reaction gas distribution and it reduces the pressure drop through the flow channels. The bio-inspired flow field increases maximum output power by 114% when compared to parallel flow field.

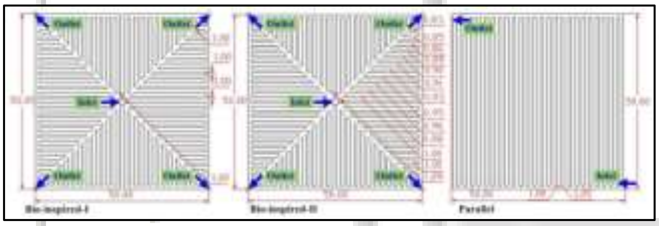
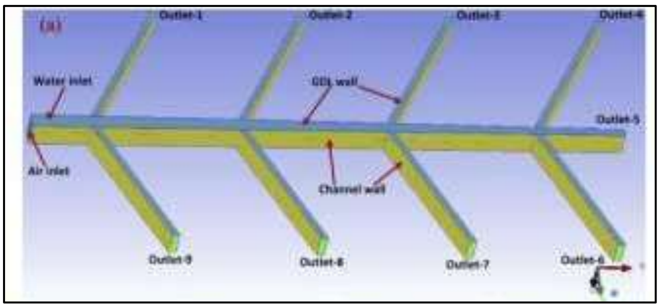
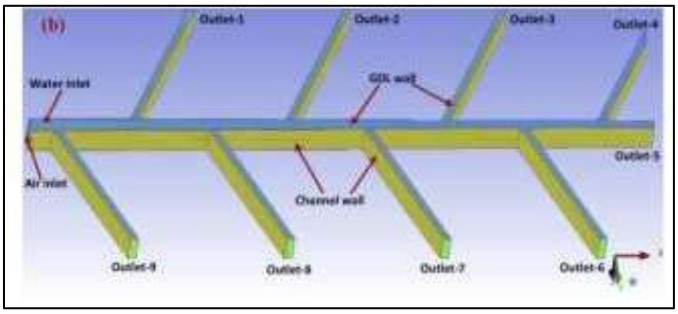


Fig. 13: Bio inspired flow field and parallel type flow field [12]

Shihua Liu et al. [13] determined that flow field which is designed by using bionics can improve the water balance of the fuel cell and make the fuel distribute uniformly in the flow field. They simulated and compared symmetric and asymmetric bionic flow fields under gravity (as shown in Fig.14). They noted that the distribution characteristics of liquid in the flow channel changed under the influence of gravity. Their simulation studies show that gravity has a major impact on the liquid water transport mechanism in the bionic flow channel. They concluded that the I–V curve results indicate that the PEMFC with asymmetric bionic flow channel has the best output in perpendicular orientation.



(a)

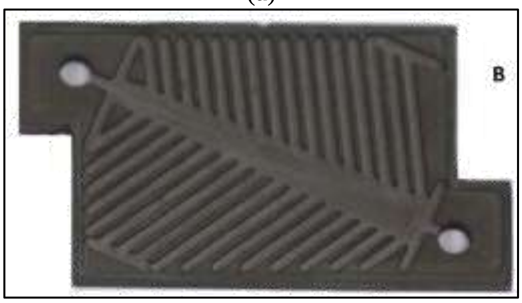


(b)

Fig. 14: (a) Symmetrical bionic flow channel, (b) Asymmetrical bionicflow channel [13]

Safaa A.Ghadhban et al. [14] conducted an experimental investigation to study the effects of using the bio-inspired flow field configurations on the performance of PEMFC. They used PROTIUM-150 type fuel cells in six-cell arrangements. They proposed two new flow fields inspired by biological substance with an active region of 9.84 cm2 (i.e., leaf veins form (b), tree shape (c) as shown in Fig.15). They compared the proposed flow field's power and polarization curves with a single serpentine flow field. According to their findings, the output of PEMFCs with leaf veins flow fields outperforms those with single serpentine flow fields by 5.12 percent and tree-shaped flow fields by 3.75 percent. They concluded that the leaf veins-shaped flow field performs better than other flow fields.

(a)



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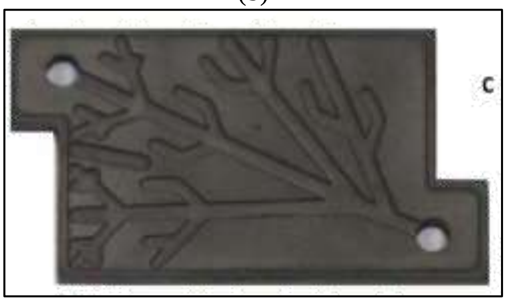
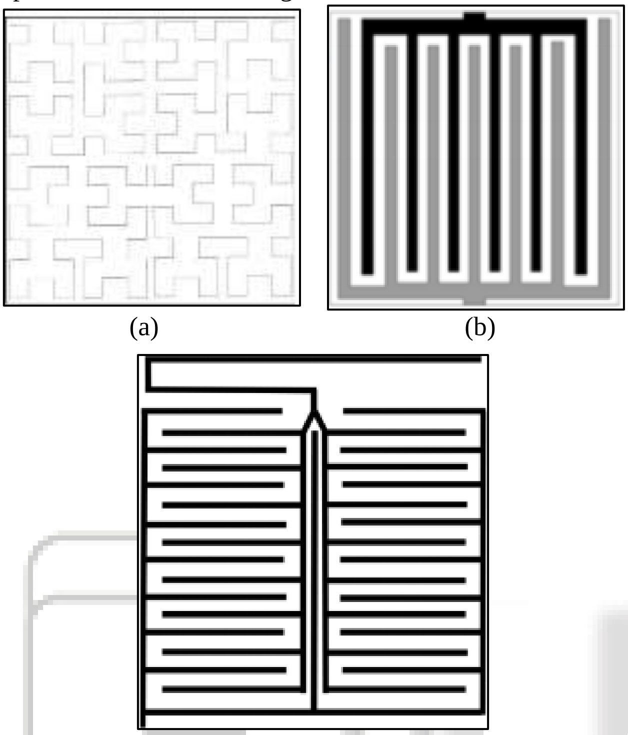


(c)

Fig. 15: (a) Single channel flow field, (b) Leaf vein shaped flow field, (c) Tree shaped flow field [14]

A. Iranzo et al. [15] presented a literature review covering bipolar plate designs based on both natural or biological structures such as fractals, leaves or lungs. The biological inspiration comes from the fact that fluid distribution systems found in plants and animals such as leaves, blood vessels. They considered the flow field designs for their experiments as shown in Fig.16.



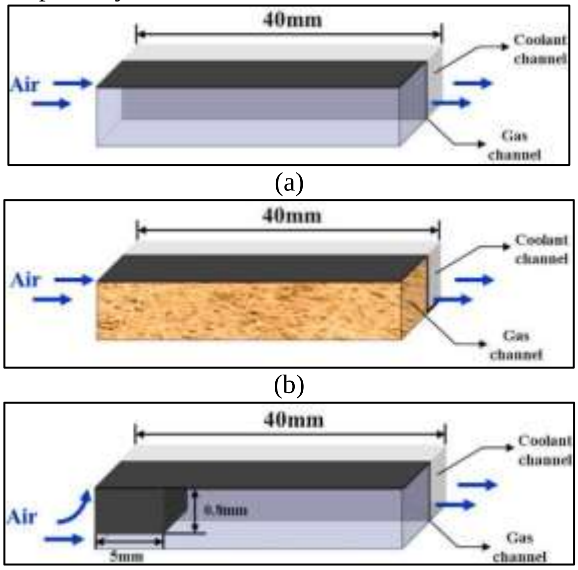
(a) (b)

(c)

Fig. 16: (a) Fractal geometry, (b) Lung-shaped flow field, (c) Murray interdigitated flow field [15]

M. Muthukumar et al. [16] reviewed the effects of different flow channel with cross sectional shape and the effects of the flow channel designs on the performance of PEMFC. They thought that the performance increment depends on cross section of flow channel. They concluded that, when the flow channel areas are varied the performance is increased, because the fuel is forced on the gas diffusion layer with the enhancement of the performance.

Nammin Lee et al. [17] proposed two conceptional cathode flow field designs for preventing electrolyte dehydration in Polymer Electrolyte Fuel Cells PEFC (passive type). They proposed three single channel designs. Fig.17(a) represents the parallel flow channel, Fig.17 (b) represents Cathode flow field with metal foam, and Fig.17 (c) represents reduced inlet of flow channel. They inserted porous material into parallel channels in one design. The other design has smaller inlet to reduce the amount of reactant air entering the MEA (Fig.17(c)). They used 3D multiscale two-phase PEFC simulations to test the cathode flow field designs. They analysed and compared the designs through numerical simulations. Their simulation results show that the metal foam-based design improves water retention in the MEA even when dry air is supplied in excess. Their results revealed a new approach to designing the cathode flow field for passive air-cooled fuel cells that work optimally.



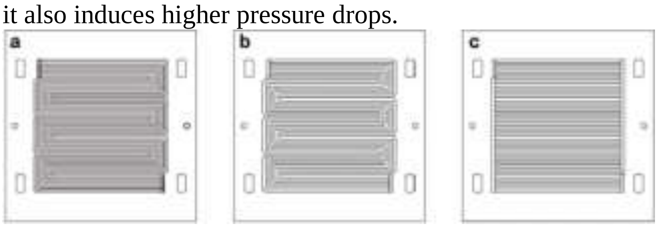
(a)

(b)

(c)

Fig. 17: (a) Cathode flow field- parallel, (b) Cathode flow field with metal foam, (c) Cathode flow field reduced inlet [17]

Rodolfo Taccani & Nicola Zuliani [18] considered high-temperature Poly- benzimidazole (PBI) PEM is highly used because their operative temperature range (120e180 C) which increases the tolerance to carbon monoxide. In this analysis, they concentrated on the effect of high-temperature PBI PEM composite bipolar plate's flow field geometry on the performance of the cell. For this reason, they analyzed two serpentine flow fields and a parallel channel flow fields for three separate channel geometries. In Fig.18, the serpentine and parallel flow fields are shown. They conducted several simulations with these flow fields. From the experimental results they concluded that serpentine geometry produces higher efficiency, although with the cell it also induces higher pressure drops.



(a) (b) (c)

Fig. 18: (a) 5 step serpentine pattern, (b) 4 step serpentine patterns, (c) Parallel channel pattern [18]

Muthukumar Marappan et al. [19] considered the water accumulated between the interface region of the GDL and the rib of the cathode flow field can be removed and filled with the Porous Sponge Inserts (PSI). They conducted experimental on PEMFC for the various reaction areas, namely 25, 50, and 100 cm2. They maintained a stoichiometry value of 2 for all experiments to avoid variations in power density. Their experiments include two flow fields, namely Serpentine Flow Field (SFF) as shown in Fig.19(a) and Modified Serpentine with Staggered Flow Field (MSSFF)as shown in Fig.19(b). They obtained peak power densities on MSSFF as 0.420 W/cm2, 0.298 W/cm2 and 0.232 W/cm2 and it is compared to SFF which yields 0.242 W/cm2, 0.213 W/cm2 and 0.171 W/cm2 for reaction areas respectively. They concluded that using 4 mm PSI increases PEMFC's efficiency by enhancing water control.

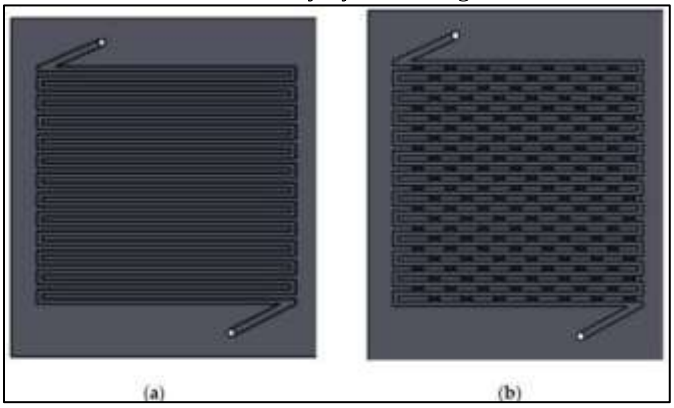


Fig. 19: (a) Serpentine flow field, (b) Modified Serpentine with Staggered provisions of 4 mm porous sponge inserts Flow Field [19]

E Alizadeh et al. [20] studied the distribution of reactant gases in PEMFC. With their studies they found out problems such as flooding or drying of the membrane are caused by the non-uniformity of design parameters. It could result in a reduced Membrane Electrode Assembly (MEA) lifetime. Considering this problem, they introduced and explained a new cascade type serpentine flow field design as shown in Fig.20. Their results show that the cascade type flow field produces a uniform current density and local stoichiometry as well as improved water management.

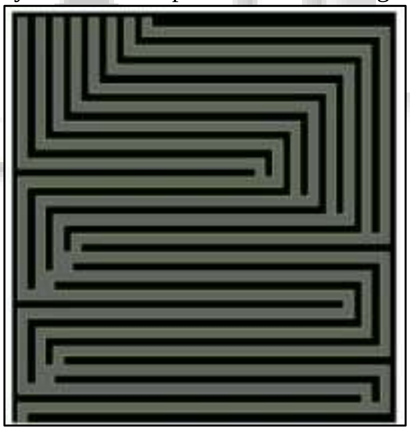


Fig. 20: Cascade type flow field [20]

M. Muthukumar et al. [21] studied about the performance of serpentine, uniform & zigzag pattern pin type. They had an idea of adopting porous carbon inserts on rib surface of cathode flow channel. They inserted porous carbon material to reduce the water flooding in between channel ribs of PEMFC. They observed the water accumulated in the cathode are removed by the capillary action of porous inserts. They investigated about the effect of porosity of carbon inserts on PEMFC performance.

M. Muthukumar et al. [22] considered that the narrower, wider and tapered channels have more power increment, because of increased flow velocity. In this study, they investigated and analysed the effect of operating conditions such as pressure and temperature on the performance of outlet tapered single channel PEMFC by using ANSYS. They compared the tapered channel with a straight channel. Their experimental results show that the peak power density occurs in the temperature of 323K with the pressure of 2 bar. They conclude that, in geometrical conditions, the outlet tapered channel has more power increment, then the straight channel.

M. Muthukumar et al. [23] found the numerical values of the operating temperature and pressure of the PEMFC. They modelled and analysed a single channel PEMFC with active area of 60 mm2 using COMSOL software. They operated the fuel cell at different temperatures of 40°C, 50°C, 60°C, 70°C and 80°C with the operating pressures of 0.5 bar, 1 bar, 1.5 bar and 2.0 bar. They obtained 20 combinations of current density values of the fuel cell at different cell voltages for the above temperatures. Their experimental results show that the maximum power density was obtained at the operating pressure of 2 bar and operating temperature of 40°C to the cell potential of 0.35 V.

Mingfu Yu et al. [24] developed a modified current distribution measuring device to measure the current density of HT-PEMFC. They conducted several simulations to know the flow direction of current density in the FC. Their experimental results shows that current density decreases along the reactant gas flow direction. They concluded that optimal hydrogen flow rate improves the performance of the HT-PEMFC.

Muthukumar et al. [25] developed and analysed the numerical model of single channel PEMFC by using COMSOL Multiphysics 4.2 software. They used standard orthogonal array of Taguchi method to conduct the optimization of design and operating parameters in two stages. From the first stage of analysis, it was found that back pressure had maximum effect and rib width and it had least effect on cell's performance. In the second stage of analysis, they performed fine-tuned optimization on selected factors which caused for 3% increase in power density and the results were also gained by using COMSOL Multiphysics 4.2.

Muthukumar Marappan et al. [26] analyzed PEMFC with two different membranes. They considered Nafion 117 and Nafion 212 as membranes for the experiments. They did several analyses on these membranes. They chose serpentine flow field on both cathode and anode sides. They designed and analyzed the PEMFC having active area of 11.6 cm2 with best-operating conditions. Their experimental results show that the PEMFC with Nafion 212 membrane generates more power when compared to the PEMFC with Nafion 117.

Muthukumar Marappan et al. [27] studied about the performance of various conventional, modified, hybrid flow field designs of the PEMFC. They also observed the tapering, bending effects of channel, landing width ratios, cross section of channel and insertion of blockages/pin-fins/baffles/inserts. By using the values obtained in the experiment i.e,. operating parameters like temperature and pressure, power density of the flow field designs, physical parameters like active area, dimensions of channel/rib, number of channels they prepared a tabulation of all values.

Huicui Chen et al. [28] considered that gas starvation is one of the most important causes of the PEMFC's lifetime decay. They determined it could lead to a series of severe consequences such as cell reversal, and output performance degradation. In this research, they studied the causes, severe consequences, diagnostic methods, and mitigation measures of the gas starvation in PEMFC's through literature review. Their research is aimed to provide guidance to the diagnosis methods and to optimize the system control strategy.

Muthukumar Marappan et al. [29] found out water removal is better flow channel which in turn increases PEMFC performance by using porous carbon inserts. They compared the flow fields with porous sponge inserts and porous carbon inserts. They did several experiments using both flow fields. Their experimental results show that the porous sponge inserts yield more performance when compared to porous carbon inserts. They concluded that by increasing the size of the porous inserts improves the performance of PEMFC.

Jun Shen et al. [30] discovered that sufficient membrane hydration requires proper water control. To investigate the effect of porosity on the efficiency of a PEMFC, they proposed a partially flooded model. Flooding occurs at low relative humidity due to high temperatures, and flooding prevents mass transfer by decreasing porosity in the GDL, according to their findings. Whereas partial flooding has no consequence on the fuel cell's capacity to create power, it does results in an unequal distribution of current density, which leads to failure. Long-term service suffers the consequences of this.

Dilek Nur Ozen et al. [31] investigated the effects of operating conditions on the performance of a PEMFC. The humidification of the inlet gases has a positive effect on cell production, according to their experiments. They noticed that when the cathode gas is humidified, the cell's efficiency increases more. The operating temperature and inlet gas temperatures are often considered to be the most important parameters.

Qin Chen et al. [32] presented the reports of thermal analysis of fuel cells like temperature changes and time constants. They found that due to the low operating temperature (80 °C), cooling PEMFC stacks is much more difficult than cooling standard combustion engines. They also compared different PEMFC cooling methods. They also examined at the subfreezing state in detail and evaluated key parameters. They also investigated the effects of thermal, humidity, and freeze/thaw cycles on degradation, such as delamination and Electrochemical Active Surface Area (ECSA) loss.

Lei Xing et al. [33] developed a fuel cell unit with 5-fold parallel channel and they separated it into 5 individual layers. Each layer's Pt loading and operating temperature were individually regulated. They noticed that as the temperature approached the outlet, the catalytic activity improved and the water content decreased. They also observed that raising the temperature compensates for the lack of catalytic activity caused by lower Pt heating.

Tolga Taner [34] aims to investigate the performance effects of PEMFCs and to optimize water conditions. For micro-scale modelling, he demonstrated the efficiency of a platinum-plated catalysed anode. His results indicate that PEMFC water management is long-lasting. It also provides information on the amount of water output that is optimised, as well as the cell longevity and energy efficiency of PEM fuel cells.

O. S. Ijaodola et al. [35] presented a research work associated with the effect of water flooding and management in PEMFC. To prevent dehydration and flooding, they confirmed the importance of maintaining a proper water balance in cells. They described and analysed the situation in order to keep the PEM hydrated even though there was a lot of water condensation. Their study compares the efficiency of new non-intrusive in-situ water identification, tracking, and characterization techniques. They wrap up with a review of recent research into various methods for preventing water flooding and encouraging proper water management in PEM fuel cells.

M. Muthukumar et al. [36] considered the natural petroleum by-product will come into in-existence and unavailable in future. As a consequence, they researched about conventional energy sources. They developed the concept of vehicles that operate in fuel systems. They found that various attempts are being made to integrate fuel cell systems into automobiles. They addressed the difficulties in introducing fuel cell operating vehicles within that article. They also spoke about how different vehicle manufacturers are designing and developing Fuel Cell Electric Vehicles (FCEV).

Wei-MonYan et al. [37] investigated thermal management of high-powered air- breathing PEMFC stacks using different cathode flow channels to improve cell efficiency. According to their findings, combining the 50% and 58.3% opening ratios in an air- breathing stack lowers stack temperature and improves temperature distribution uniformity. They also discovered that it improves and stabilizes stack efficiency. They concluded that the average temperature over the cross-sectional flow region from the simulation was the best fit for the simulation results and the data.

Muhammad Faizan Chinannai et al. [38] investigated the geometry of fuel cell model which can affect the performance. Using a three-dimensional, two-phase, multiscale PEM fuel cell model, they simulated various fuel cell malfunctions based on the realistic coolant flow control technique. They noticed a shift in coolant flow rate, which is a clear indication of fuel cell failure. They also discovered that the increase in cell temperature is not always proportional to the amount of voltage degradation. The current density distribution has the greatest impact on the temperature rise of the cell. At a low current density of 0.3 A cm-2, they ran a numerical comparison between the standard and malfunctioning situations.

Lingchao Xia et al. [39] studied the effects of temperature, membrane's thickness, and catalyst layer's thickness in HT-PEMFC by using a 3D model in COMSOL. To investigate the effects on efficiency, they used polarisation curves. Their findings show that increasing the temperature of a fuel cell will improve its efficiency. When it comes to the effect of catalyst layer thickness, the cell output improves as the thickness of the catalyst layer decreases. The effect of membrane thickness on fuel cell efficiency has been discovered to be that a thinner membrane can achieve better performance. They came to the conclusion that their results could be used to direct the operation and design of HT-PEMFC in practical applications.

Muthukumar. M et al. [40] identified the parameters influencing the performance of PEMFC. Pressure, temperature, anode and cathode inlet mass reactant mass flow, relative humidity, and design parameters were all investigated in this paper. They conducted several experiments on a single channel serpentine flow field with channel widths of 1:1, 1:2, 2:1, and 2:2 on a serpentine flow channel with a 25cm2 active region. Creo Parametric 1.0 and CFD Fluent 14.0 software were used. They built a 3D model and ran simulations on it. Taguchi and Minitab 17 tools were used to conduct the study in two phases. The Taguchi method achieved 97.60 percent square of response factor from the first step, according to their findings. They were able to achieve power density variations.

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