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Influence of flow field and gas diffusion layer on polymer electrolyte membrane fuel cell performance

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Abstract: In the present study flow field in the bi-polar plate and gas diffusion layer (GDL) of 1.2 kW Nexa fuel cell (FC) training system having serpentine flow field has been taken for examine. The channel dimension and shape in the flow-field of the bipolar end plates have been taken into examination. Pressure drops with hydrogen flow rate and channel length. For enormous hydrogen inputs, the optimal measurement is around 1.5, 1.5 and 0.5 mm for the values of channel width, channel depth and width of land, corresponding research on the effect of channel designs revealed that semi-circular, rectangle and triangular-shaped and found, the land width for triangular and semicircular-shaped are almost zero millimeters which increase the water vapor accumulation, due to which the losses increase. But there are very few losses in the polarization curve seen in the square cross section because there is very little water vapor buildup. AGDL is an essential component of an FC. The three-dimensional model of the GDL is simulated using COMSOL metaphysics 4.2 and observed that increased porosity facilitated the entry of more reactants into the reaction side, resulting in increased current density. Low membrane thickness resulted from excessive current density in the membrane thickness. GDL provides reactant species that raise the rate of consumption at the point where the catalytic layer and GDL interface. The outcomes of the simulation are contrasted with experimental data found in published work. The comparison demonstrates that the modeling outcomes and the experimental data agree quite well.

Keywords: PEMfuel cell, bipolar plate, flow channel, gas diffusion layer, membrane thickness

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1. Introduction

An electrolyte membrane fuel cell (FC) consists of electrodes (cathode and anode). The cathode has a positive charge and the anode has a negative charge. The anode (positive) side oxidation of hydrogen (H_2), while oxygen (O_2) is diminished on the cathode(negative) side. From the anode to the cathode proton is transported through electrolyte membrane. While the peripheral circuit carries electrons from the anode to the cathode. Fuel cells (FCs) employ certain materials to transfer hydrogen protons from molecule to molecule keeping them in their ionic condition. Protons move via a polymer membrane with a Tefl backbone composed of per sulfonic acid groups. When a load is needed the electrons go to the conductive substance that attract them. Heat and water are generated on the cathode when oxygen interacts with electrons and protons, Nguyen et al., (1993). To enhance the rate of electrochemical reactions, a catalyst is present in both the cathode and anode. As illustrated in Figure 1.

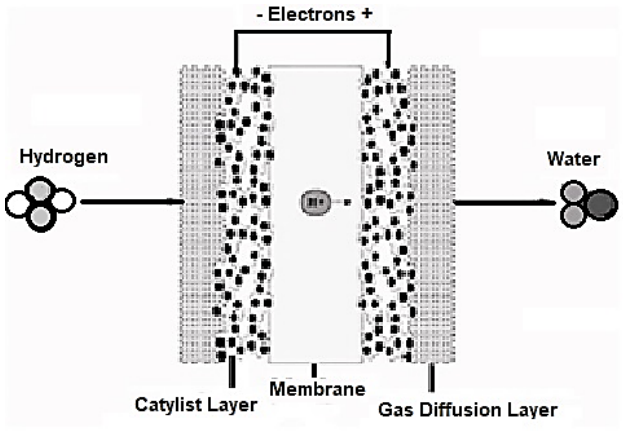

Figure 1(a). Basic fuel cell structure. Patel et al. (2016).

The following reactions is typical of a proton exchange membrane (PEM)-FC or PEM FC. Jang et al. (2006).

$H_2=2H^+ + 2e^-$……(Anode)

$1/2O_2 + 2H^+ + 2e^- = H_2O$ (l)……....(Cathode)

$H_2 + 1/2O_2 = H_2O$+ electric energy + waste heat

In order to share fuel and oxidant equally and collect acquire current to power the required equipment. The actual FC layers or membrane electrode assemblies (MEAs) must be built. The cell must be arranged in a FC stack. Single-sided flow field bipolar plate is the only kind of cell in fuel FCs with one cell, however bipolar plates, which have flow fields on both sides are typically present in FCs with several cells. In FCs, bipolar plates serve a variety of purposes. They disperse oxidant and fuel inside the cell, divide the stack's individual cells, gather current, remove water vapor from cell, humidify the gasses and maintain the cell temperature. Middelman et al. (2003).

Nomenclature

Ac- Cross-sectional area, (cm^2)	Greek symbol
P_c Perimeter, (cm)	η Efficiency of fuel cell
V Velocity, (m/s)	μ Chemical potential
X Mole fraction	ρ Density
m^o Hydrogen flow rate, (g/min)	αcharge transfer coefficient
f Friction factor	ξ Stoichiometric ratio of gases
$Q_{stack}H_2$Flow rate, (m^3/s)	Superscripts
S_m Electrochemical reaction	ref reference
D_H Hydraulic diameter, (cm)	theo theoretical
w_c Channel width, (cm)	cons concentration
A_{cell} Cell active area, (cm^2)	
N_{ch} Number of parallel channels	

These functions need the employment of particular plate materials and designs in order to be completed simultaneously. Straight, serpentine, parallel pin-type flow fields are examples of frequently used designs. Selection of materials based upon stack volume/kW, strength of the material, chemical reliability, and corrosion resistance, gas diffusivity impermeability, manufacturing capability, electrical conductivity and density. The materials that are most frequently utilized are doped polymers, stainless steel and titanium nonporous graphite. Numerous composites have been studied and starting to manufacture in large quantities. Resin-impregnated graphite is used to make most PEM FC bipolar plates. Although graphite is highly conductive and prevent from corrosion, its production is pricey. The bipolar plate surfaces of graphite or stainless steel have flow channels that are either electrochemically secured or naturally milled.

These methods aren't suitable for mass manufacturing, that is why researchers are actively looking at new bipolar materials and manufacturing techniques. According to Springer et al. (1991), the GDL porosity and morphological characteristics of thickness affects transport of reactants and products. There has also been a description of some recent research on how the shape of the GDL affects FC performance. Jordan et al. (200) studied the influence of porosity in this assembly, and Lee et al. (2004) carefully considered GDL

fabrication techniques for varying thicknesses. Mathematical modeling provides a consistent way to analyze FC performance while taking into account cost. Currently most of the theoretical research employing numerical simulation is used to advance FC components such catalyst surfaces, flow field design, and proton exchange membranes (PEMs) in order to achieve high FC performance. Developed a FC model to analyze FC performance, Bernardi and Verbrugge (1991). The FC presentation under various porosity, thickness, and humidity conditions was predicted by this model. However, the physical characteristics of the GDL and the impact of bipolar plates on the GDL are not covered in this study. The amount of oxygen beneath the bipolar plates land area in a physical FC is less than that beneath the channel areas, Cheema et al. (2011). Thus, this also becomes an important factor in altering the cell's performance in addition to the GDL's thickness and porosity, Roshandel et al. (2005). Due to this circumstance a 3D model is developed, allowing this influence to be more closely modeled after the actual FC process. This served as the study's inspiration. Ramesh and Duttagupa (2013). To examine FC performance, we have used the bi-polar plate and Gas diffusion layer (GDL) of 1.2 KW Nexa fuel cell (FC) training system having serpentine flow field has been taken for examine. The Nexa Training System Figure1(b) has inbuilt 1.2 KW fuel cell system

Figure 1(b). 1.2 KW Nexa fuel cell (FC) training system IP Sahu et al. (2014).

The fuel cell module, hydrogen storage system, battery and power electronics can be examined or influenced either individually or combined. O'Hayre et al. (2016). A complete energy system designed for use in laboratories is the Nexa Training System. It can be easily included into bigger breadboard setups after it is configured. Realistic applications can be shown throughout this process in this research the effectiveness has been examined for varying gas diffusion (GDL) porosity and thickness. Advancements in the influence of flow fields and gas diffusion layers (GDLs) on Proton Exchange Membrane (PEM) fuel cell performance have been significant in recent years. These components are crucial in determining the efficiency, durability, and overall performance of PEM fuel cells. Here are some key advancements.

1.1. Flow fields

(a). Optimized flow field design:

Channel-Rib structures: Advances in the geometry of flow fields, such as serpentine, parallel, and interdigitated patterns, have improved gas distribution, water management, and pressure drop.

3D Flow fields: The development of three-dimensional flow fields, which can provide more uniform gas distribution and enhanced water removal. Yang and Zhao (2023).

Bio-inspired designs: Utilizing patterns inspired by nature (e.g., leaf venation) to enhance reactant distribution and water management.

(b). Computational fluid dynamics (CFD) simulations:

Enhanced simulation techniques have allowed for better prediction and optimization of flow field designs, leading to improved performance and reduced experimental costs.

(c). Materials and manufacturing techniques:

Advances in materials, such as the use of corrosion-resistant coatings and novel fabrication methods (e.g. additive manufacturing), have improved the durability and performance of flow fields.

1.2. Gas diffusion layers (GDLs)

(a). Material innovations:

Development of new materials, including carbon paper and carbon cloth, with enhanced properties such as higher porosity, better hydrophobicity, and improved electrical conductivity Incorporation of micro porous layers (MPLs) to improve water management and reduce flooding.

(b). Structural enhancements:

Tailoring the microstructure of GDLs to balance gas permeability and mechanical strength and optimization of the thickness and composition of GDLs to improve reactant transport and water management.

(c). Hydrophobic treatments:

Advanced hydrophobic treatments and coatings to enhance water repellency, thus improving water management and reducing flooding issues.

(d). Characterization techniques:

Improved characterization methods, such as X-ray tomography and scanning electron microscopy (SEM), to better understand the properties and performance of GDLs.

Integrating flow field and GDL designs to create synergies that enhance overall cell performance. Customizing flow fields and GDLs for specific operating conditions and applications. Vielstich et al. (2023). Development of more sophisticated testing protocols and diagnostic tools to better assess the performance and durability of flow fields and GDLs under various operating conditions. Addressing degradation mechanisms through better material selection and design improvements to prolong the lifespan of PEM fuel cells. Continuous efforts to optimize the interaction between flow fields and GDLs, focusing on parameters like reactant distribution, water management, thermal management, and electrical conductivity. Utilizing machine learning and artificial intelligence to predict and optimize flow field and GDL designs, leading to faster and more efficient development cycles and exploring sustainable and Low-cost materials to reduce the environmental impact and cost of PEM fuel cell. Addressing Challenges related to the scalability and manufacturability of advanced flow field and gas diffusion layer design for commercial applications. These advancements are contributing to the continuous improvement of PEM fuel cells, making them more viable for a wide range of applications, from portable electronics to automotive and stationary power systems. Taylor and Krishna (1993).

2. Methodology

2.1. Modeling of flow field

The primary objective of these is to study how the bipolar flow field is influenced by size and shape of the channel. Three distinct zones make up the half-cell PEMFC. The issue domain of the model. The flow-field channels on the bipolar plates are in a serpentine pattern with two layers, an electrode for gas diffusion and a catalyst layer.

2.2. Problem domain

The bipolar plate serpentine flow-field design with square cross-section channels is depicted in Figure 2 we have utilized a wide range of channel dimensions since we are researching how FC performance is affected by channel dimensions. There were variations in the channel depth, land breadth, and channel width. The domain's active region measured 10.5 *10.5 cumin length and width.

2.3. Model assumptions:

The half-cell model was created using the following presumptions in order to investigate how channel dimensions affect FC performance.

1. Gravity's effect was disregarded in the single cell stack; there are stationary and steady state conditions.
2. The cell domain contains isothermal conditions.
3. The FCs laminar flow is designed by a Reynolds number.
4. The gas is moving through the tubes as well. It is using the catalyst as a response as well.
5. The channels are unable to maintain a constant temperature.
6. The waterways have a lot of twists and curves that need to be taken into consideration

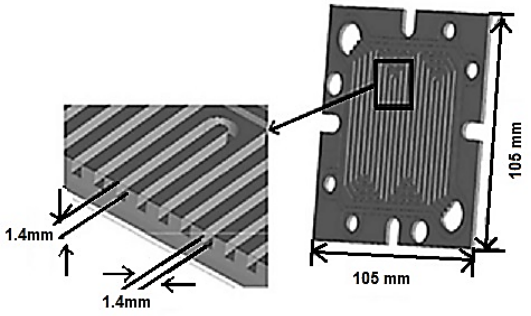

Figure 2. Typical channel diameters in a bipolar plate with serpentine flow-field design.

2.4. Modeling of GDL

Figure 3 depicts three-dimensional (3D) channel model that was utilized in simulation investigations on anode and cathode sides, there was only one parallel flow channel to act as a mediator among the two GDLs, a PEM is positioned between them, facilitated by catalyst layers. The geometric parameters and operating conditions used to simulate PEMFC shown in Table 1.

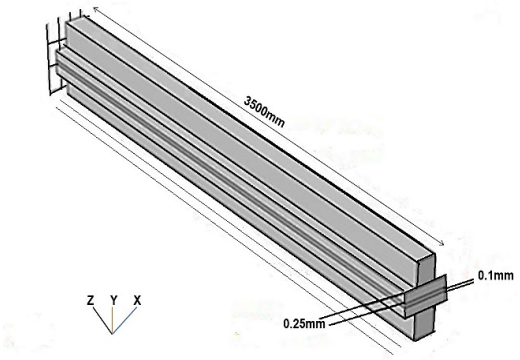

Figure 3. The simulation-based PEM fuel cell model.

Table 1. The geometric parameters and operating conditions used to simulate PEMFC performance.

FC length	3500.00mm
FC Channel height	1.400mm
FC Channel width	1.400mm
FC Porous electrode thickness	0.250 mm
FC Membrane thickness	0.100 mm
Porosity of GDL	0.400
Inlet H_2 mass fraction (anode)	743 E-3

Outlet H_2O mass fraction (cathode)	23E-3
Inlet oxygen mass fraction (cathode)	228E-3
Anode inlet flow velocity	0.200m/s
Cathode inlet flow velocity	0.500m/s
Viscosity of Anode	1.19 E-5 Pa.s
Viscosity of Cathode	2.46 E-5 Pa.s
Permeability (porous electrode)	2.36 E-12 m^2

2.5. Assumptions

Based on following presumptions model is suggested to function.

1. The cell runs at isothermal and steady state temperatures.
2. All species have ideal gas, and their flow is laminar.
3. It is not thought that deformations happen anywhere in the cell.
4. The membrane's permeability values for gas transport are extremely low, making it Impenetrable.
5. Since water only exists as vapor, there is only one phase of flow in the cell.

3. Governing equations

Equation for mass conservation

$$\nabla .(\rho u) = 0 \tag{1}$$

Momentum conservation equation, Rowe and Li (2001).

$$\nabla.(\rho u.u - \mu\nabla u) = \nabla.(\rho + \frac{2}{3}\mu\nabla.u) + \nabla.(\mu(\nabla u)^T) \tag{2}$$

Energy conservation equation

$$\nabla.(\rho u h) - \nabla.(k\nabla T) = 0 \tag{3}$$

$$\nabla.(\rho u Y_i) - \nabla.(\rho D_{(ii)}\nabla Y_i) = \nabla.(\rho D_{(ij)}\nabla Y_i) \tag{4}$$

$$\frac{\partial(\rho v_x)}{\partial x} + \frac{\partial(\rho v_y)}{\partial x} + \frac{\partial(\rho v_z)}{\partial x} = S_m \tag{5}$$

Where ρ = density

$$S_m = -\frac{\lambda|H_2|}{k+|H_2|} \tag{6}$$

When domain's hydrogen content is denoted by [H2],

$$q = \frac{4ba^3}{3\mu} \times \frac{\Delta p}{\Delta x}\left[1 - \frac{192}{\pi^3 b}\sum_{i=1,3,5....}^{\infty} \frac{tanh(i\pi b/2a)}{\rho}\right] \tag{7}$$

$$q = \frac{\sqrt{3}a^4}{320\mu}\left(\frac{-\Delta P}{\Delta x}\right) \tag{8}$$

$$q = \frac{a^4}{4\mu}\left(\frac{-\Delta P}{\Delta x}\right)\left[\frac{\tan(x)-\alpha}{4} - \frac{32a^4}{\pi^5} \times \sum_{i=1,3,5....}^{\infty} \frac{1}{i\left(i+(2\alpha/\pi)\right)^2\left(i-(2\alpha/\pi)\right)}\right] \tag{9}$$

3.1. Pressure drop in channels of flow

Since the flow fields of many types of FCs are often set up as the pressure drop across a channel, which has several flows of channels is parallel, also symbolizes the decrease in pressure across the FC. The velocity is raised by raising the pressure drop between the intake and output. Bipolar plate channels normally have laminar flow that is proportionate to the rate of flow. The incompressible flow equations help to find the pressure drop (Spiegel et al., 2008).

$$\Delta P = \frac{f L_{Cha} v^2 \rho}{2D_H} \tag{10}$$

Where L_{cha} = length of channel, f = friction factor, D_H=Dia. Ofhydraulic, ρ = density of fluid, v = average velocity,

The hydraulic diameter is defined as:

$$D_h = \frac{4 \cdot \text{area}}{\text{wetted perimeter}} = \frac{4A}{P}$$

$$D_H = \frac{4A_C}{P_C} \tag{11}$$

Where A_c is the cross-sectional area and P_c is the perimeter. For the typical rectangular flow field, the hydraulic diameter can be defined as:

$$D_H = \frac{2W_c d_c}{W_c + d_c} \tag{12}$$

Where w_c is the channel width, and d_c is the depth. The channel length can be defined as:

$$L_{Chan} = \frac{A_{Cell}}{N_{Ch}[W_C + W_L]} \tag{13}$$

Where A_{cell}=FC active area, W_C and W_L= width of channel and the space between channels (m).

N_{ch}=number of parallel channels in FC.

3.2. Friction factor

The friction factor (f) is a dimensionless number that describes the resistance to flow due to friction along the walls of the flow channel. It is essential for determining pressure drops in the channels, which affect the overall efficiency of the fuel cell.

$$f = \frac{56}{Re} \tag{14}$$

3.3. Average Velocity

The average velocity (v) of the fluid in the flow channels is crucial for determining the reactant distribution and overall mass transport in the PEM fuel cell.

The velocity at the fuel cell entrance is:

$$v = \frac{Q_{Stack}}{N_{Cell} N_{Ch} A_{Ch}} \tag{15}$$

Where, v=velocity of flow (m/s), A_{ch} is the cross-sectional area of the channel, Q_{stack}= entrance is the air flow rate at the stack(m^3/s) ,N_{cell} is the number of FC in the stack and N_{ch}= number of parallel channels in each FC.

4. Results and discussion

Different cross-sections, channel depths, channel heights, and land widths between the channels were selected for investigation. The depth of the channel in a PEM fuel cell's flow field plays a significant role in hydrogen utilization at the anode. Here's an illustration of how varying the channel depth impacts hydrogen utilization: We saw hydrogen consumption increased with increase the channel depth and found the maximum use of H_2 (84.8%) at the anode if the channel depth reached 1.4 mm and again increasing the depth beyond 1.4 mm hydrogen consumption diminished, Deep channels may lead to non-uniform hydrogen distribution, with potential for areas of stagnation and reduced utilization efficiency and deep Channels May suffer from lower flow velocities and uneven distribution, leading to areas Where hydrogen is underutilized. The present investigation based on boundary condition found the optimum depth of channel is 1.4 mm, after that, mass concentration losses increase and consumption of hydrogen decreases with an increase in depth. Fig. 4(a) illustrates the depth of channel variation's impact on H_2 utilization at the anode and width (1.4 mm) and channel width (1.4 mm).

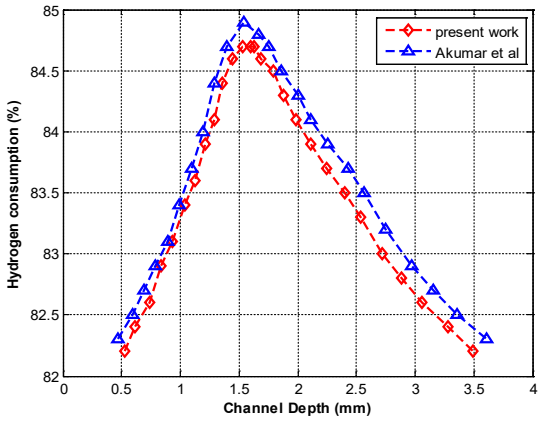

Figure 4(a). Impact of channel depth on anode hydrogen Consumption.

The obtained findings aligned with what other researchers had noticed when doing their own studies. Fuller and Newman (1993). Considering the findings, which show that the anode's hydrogen consumption rises with decreasing land width, we choose to investigate scenarios in which land width may be lowered to almost zero (0+ mm). Nevertheless, creating channel's flow-field with such modest land widths (0 + mm) for bipolar plates. Based on the previous discussion, we have chosen a bipolar plate in our simulation.

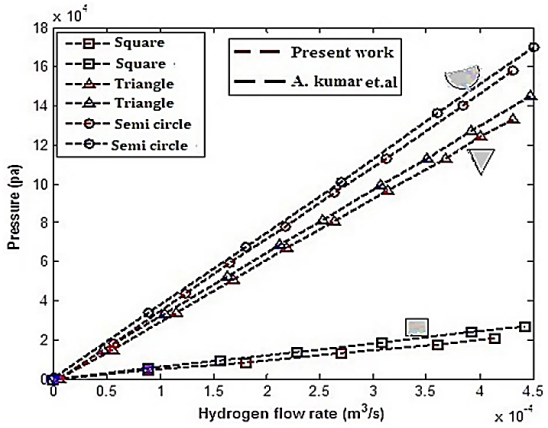

Figure 4(b). Channel shape's impact on the pressure drop.

In these plates, the channel's cross-section was triangular rather than the rectangular cross-section that is often seen in graphite bipolar plates, Kumar and Reddy (2003). We wanted to immediately to which cross-section channels will perform, so we made the decision to investigate the pressure drop in channels with various cross-sections hemispherical sector (a = 0.700 mm, b = π radians), equilateral triangle (a = 1.4 mm), and rectangular (a = 1.4 mm, b = 1.4 mm).In Figure 4(b) we can clearly see that larger pressure drop occurs in the hemispherical cross section due to inefficient use of space in the fuel cell design and height water accumulation at cathode side due (0 + mm) land width. Hemisphere channels are not space-efficient, leading to less effective packing density in the bipolar plate and also difficult to produce using standard manufacturing techniques for fuel cells. Pressure drop in triangular cross section is lower than hemisphere cross section but more than rectangular cross section with same reason water accumulation in cathode side is more due to (0 + mm). i.e. less effective at water removal, potentially leading to flooding in the narrower parts of the channel. Triangular cross section relatively uniform flow distribution in certain configurations but manufacturing complexity is more challenging to manufacture precisely the incompressible flow equations used to approximate the pressure drop. The pressure drop in relation to channel length is depicted in Figure 5(b). Especially at a small scale. Rectangular channels allow minimum pressure drop due to very less water accumulation, i.e. Rectangular channels facilitate effective water removal, minimizing the risk of flooding and dry spots. For efficient use of space, enabling a higher density of channels in the same area, which is crucial for compact fuel cell designs widely spaced flow channels improve the plate's electrical conductivity but also reduce the surface exposed to the reactants and enhance the accumulation of water. The

pressure drop across a channel also represents the pressure drop throughout the entire fuel cell since the flow fields of many different types of fuel cells are usually configured as several parallel flow channels. The gas flows from anode to the cathode by flow channel with a specific mean velocity and the flow is driven by the pressure differential between the anode and cathode. The pressure drop in a channel with hydrogen flow in a PEM fuel cell can be calculated using the equation (11), considering the channel dimensions, flow rate, and properties of hydrogen. By optimizing these parameters which are shown in Figure 5(a), Pressure drop increase with increase the hydrogen(H_2) consumption. The efficiency and performance of the fuel cell can be significantly improved.

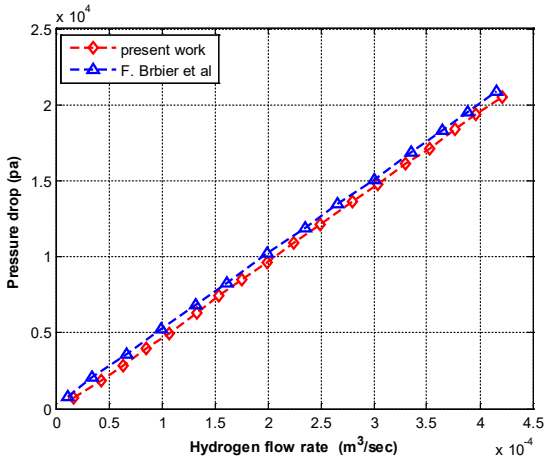

Figure 5(a). Pressure drop with respect to hydrogen flowrate.

The velocity is also raised by raising the pressure drop between the anode and cathode, flow of the hydrogen will always laminar.

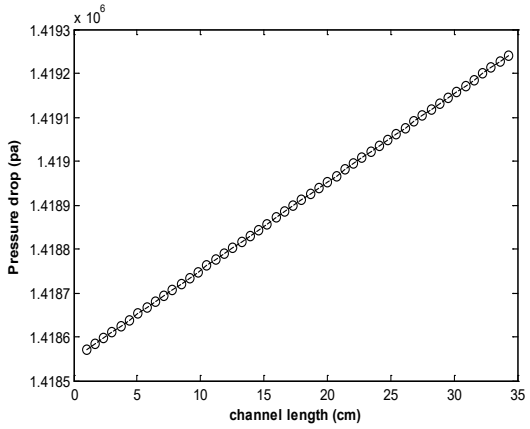

Figure 5(b). Pressure drop with respect to channel length.

The effects of pressure drop with varying width and depth are representing in Figure 6(a) and Figure 6(b). Varying the width and depth of a channel in a PEM fuel cell affects the pressure drop, we explored the relationship between these dimensions and the resulting pressure drop using the equation (11). This analysis will help to find cross-sections will function better in FCs since their pressure drop is around six to seven times. Greater than that of a rectangular cross-section channel.

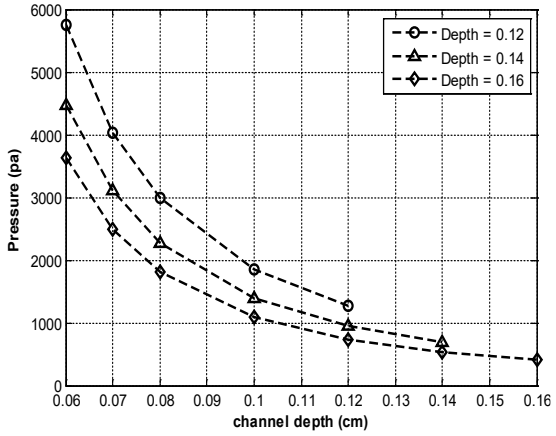

Figure 6(a). Pressure drop with different channel depth.

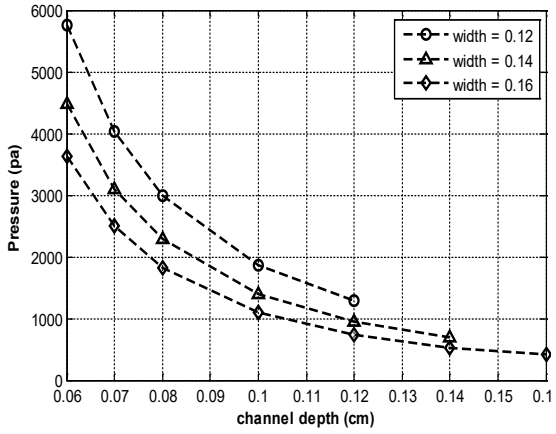

Figure 6(b). Pressure drop with different channel width.

Figure 7 shows the optimal channel dimensions for channels having a rectangular cross-section. The dimensions for a triangular cross-section and hemisphere cross-section are 1.4mm for channel width, 1.4 mm for channel depth and 0 mm for land width respectively.

The hydrogen consumption for the triangle cross-section was 92.5%, while the hemisphere cross-section were 92.9%, as shown by the bar graph Figure 7. These figures represent a about 9% increase above the 84.8% value for a cross-section with a rectangular form.

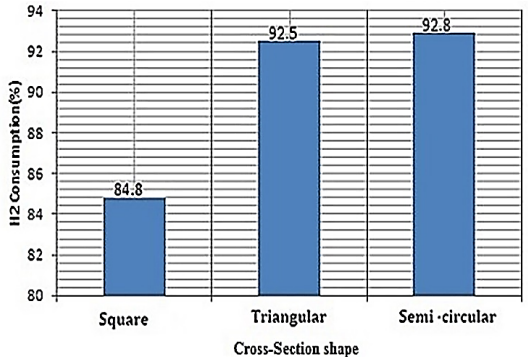

Figure 7. Impact of cross section of channel in fuel cell.

The curve between voltage and current density for different channel shape is illustrated in Figure 8 (a). It is evident from the figure that losses in the square cross section are smaller than those in the other cross sections (triangular, semi-circular and rectangular). Using cross sections other than square shapes, such as triangular and hemi-sphere increase the amount of hydrogen consumed at the anode section will function better in FCs since their pressure drop is around six to seven times greater than that of a rectangular cross-section cannel. Figure 7 shows the optimal channel dimensions for channels having a rectangular cross-section.

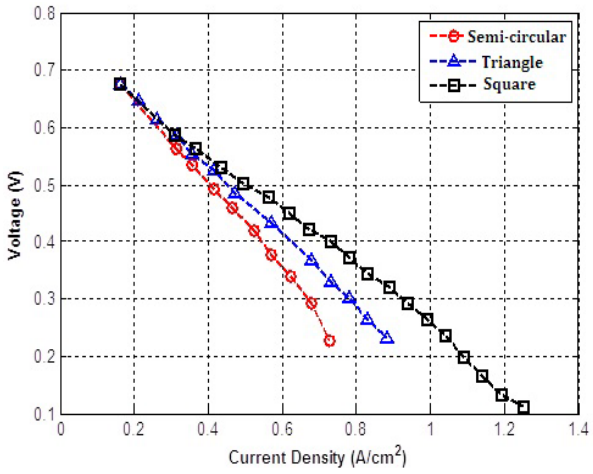

Figure 8(a). Channel cross-section effect on V-I characteristic curve.

The dimensions for a triangular cross-section and hemisphere cross-section are 1.4mm for channel width, 1.4 mm for channel depth and 0 mm for land width respectively. The hydrogen consumption for the triangle cross-section was 92.5%, while the hemisphere cross-section were 92.9%, as shown by the bar graph Figure 7. These figures represent a about 9% increase above the 84.8% value for a cross-section with a rectangular form.

The catalyst layer's membrane material is kept more hydrated by the maximum rates of water vapors for higher current densities, which increases the catalyst layer's active surface area and enhances FC performance.

Figure 8(b) illustrated that the temperature of the FC from 50 to 70 degrees Celsius. Its maximum current density also rises, Figure 9(a) shows the activation losses decrease as the exchange current density increases in concert with the fuel cell's temperature. This could explain the boost in performance. The fuel cell temperature at 90°C exhibits a lower polarization curve than the other curves in the lower current density zone. Suggesting an improvement in mass transmission as a result of diffusivity increasing with temperature. In this work, we also investigate the impacts of varying GDL porosities and thicknesses from0.2 mm to 0.5 mm and 0.15 mm to 0.6 mm, respectivelyshown in Figure 9(b), Figure 10(a) and 10(b) and found high Porosity Enhances mass transport and water management but reduces mechanical strength and the low porosity: Improves mechanical strength but can hinder gas diffusion and water removal. Thicker GDL provides better water management and mechanical stability but increases mass transport and electrical resistance and thinner GDL Improves gas diffusion and electrical conductivity but may face challenges in water management and mechanical durability.

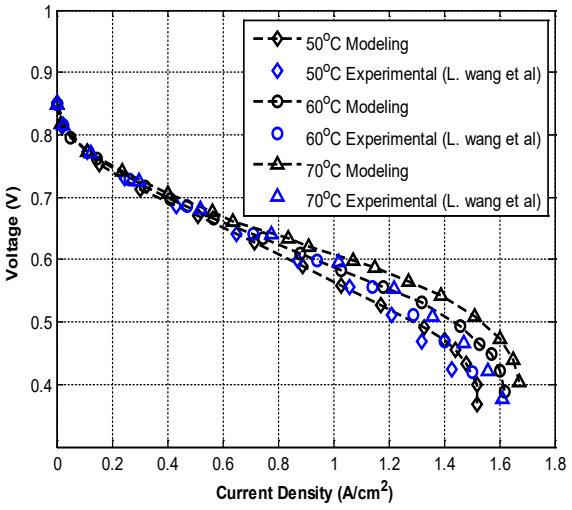

Figure 8(b). Comparison experimental data for different fuel cell temperatures.

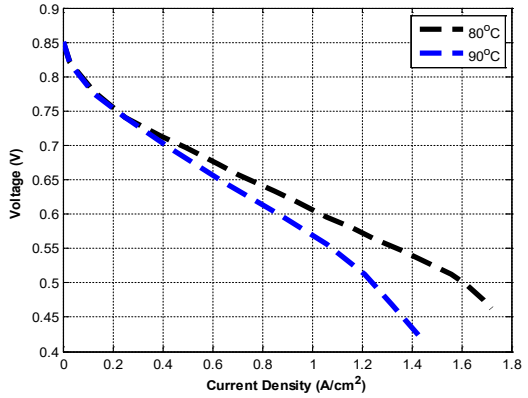

Figure 9(a). The polarization curves at different operating fuel cell temperatures (80°C and 90°C).

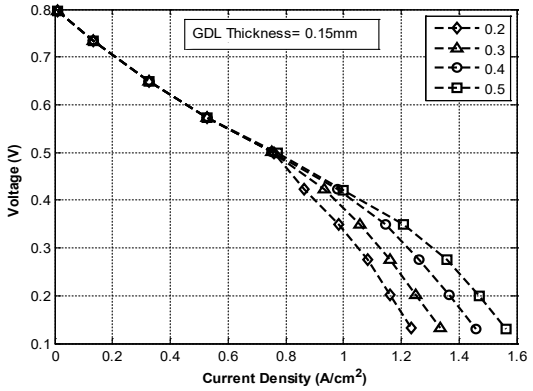

Figure 9(b). Polarization curves for different porosities with 0.15 mm GDL thickness.

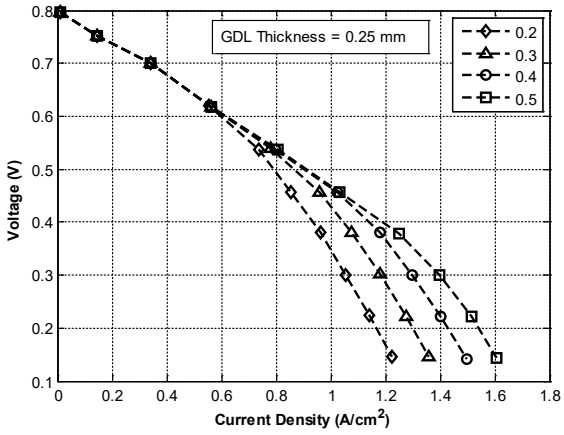

Figure 10(a). Polarization curves with 0.25 mm GDL thickness for various porosities.

Figure 11 (a) shows effect of different GDL thickness with fixed porosity 0.5. from the polarization curve up. To 0.55 mm GDL thickness current density is increasing after current density decrease when GDL thickness increase up to 0.6 mm. so it can be concluded that porosity 0.5 is better for 0.55 mm GDL.

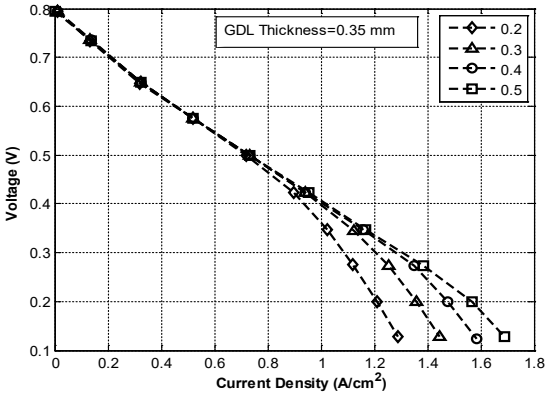

Figure 10(b). Polarization curves with 0.35 mm GDL thickness for various porosities.

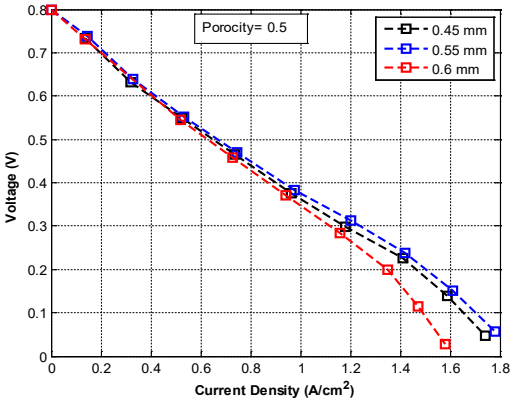

Figure 11(a). Polarization curves for different GDL.

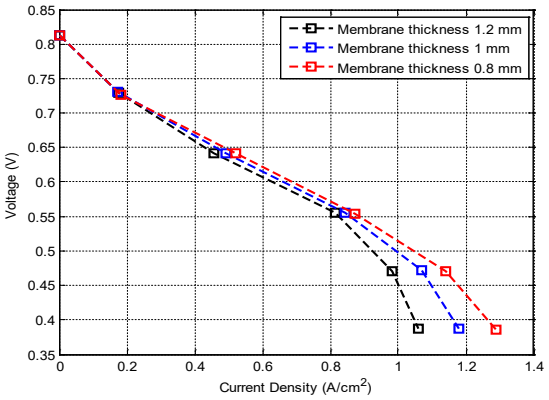

Figure 11(b). Polarization curves for different membrane thickness.

5. Conclusions

- The study's goals were to examine that the FC's effectiveness, The effects of drop in pressure with various channel dimensions length, mass flow rate and shapes. The consumption of hydrogen with channel depth in the bipolar plate and the effects of temperature, porosity and GDL thickness employing 3-D PEMFC model. It was discovered that high fuel usage the ideal channel width (1.40 mm), land width (1.40 mm) and channel depth (1.40mm) respectively.
- The effects of pressure drop illustrate that the anode will need more hydrogen when the land width decreases triangular and semicircular-shaped channels were examined and found the land width for triangular and semicircular shape is almost zero millimeters, But there are very few losses in the square cross section because non zero land width and small water vapor buildup.
- Study the effects of varying membrane thickness increase anion concentration gradient. Thickness of membrane augments the reactant concentration at the reaction site. Conductivity of ion resistance has no effect on the potential of PEM FC and decreases with decreasing membrane thickness.
- The main reasons of FC performance are declining due to reactant movement, Hence we need to boost reactant movement in the FC. Research is being done to better anticipate this difficulty.
- PEM fuel cell performance is affected by temperature in many of ways, including durability, gas diffusion, water management, membrane conductivity, reaction kinetics and overall efficiency. Performance and long-term of fuel cells may be significantly increased by comprehending and maximizing temperature impacts. Illustrated that the temperature of the FC from 50 to 80 degrees Celsius. Its maximum current density also rises, suggesting an improvement in mass transmission as a result of diffusivity increasing with temperature.
- Future research on PEM fuel cells should aim to enhance material properties, improve system integration and address environmental and economic challenges. By focusing on these areas significant advancements can be made, leading to more efficient, durable, and cost-effective fuel cell technologies suitable for a wide range of applications.
- GDLs and bipolar plates in FC have a bright future ahead of them because to continuous research into ways to increase durability, lower prices, improve performance, and customize designs for different uses. These developments will support FC technology's ongoing expansion and widespread application in a variety of industries

Conflict of interest

The authors have no conflict of interest to declare.

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