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*by A`rasy Fahrudin*

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## The effect of mother channel width on biometric flow field towards polymer electrolyte membrane fuel cell performance

A Fahrudin<sup>1,2,\*</sup>, D Ichsani<sup>1</sup>, F Taufany<sup>3</sup> and B U K Widodo<sup>1</sup>

<sup>1</sup>Mechanical Engineering Department, Institut Teknologi Sepuluh Nopember (ITS), Jl. Raya ITS, Keputih, Sukolilo, 60111, Surabaya, Indonesia

<sup>2</sup>Mechanical Engineering Department, Universitas Muhammadiyah Sidoarjo, Jl. Raya Gelam No.250, 61271, Sidoarjo, Indonesia

<sup>3</sup>Chemical Engineering Department, Institut Teknologi Sepuluh Nopember (ITS), Jl. Raya ITS, Keputih, Sukolilo, 60111, Surabaya, Indonesia

\*arasy.fahrudin@umsida.ac.id

**Abstract.** Leaf shape biometric design shows promising potential as a flow field to supply air reactants in Polymer Electrolyte Membrane Fuel Cell. However, studies that discuss the dimensions of biometric flow field in detail are rarely encountered. The channel width can affect the supply of reactants, the better the supply of reactants the better the cell performance can be achieved. In this study we investigated the effect of the mother channel width on the biometric flow field towards cell performance using numerical simulations. The model is composed of 9 layers with 25 cm<sup>2</sup> of active area. The channel dimension is varied by considering Murray's theory. Simulation results show that the optimal width of the mother channel can increase power density by up to 6% compared to other variations. This increase can be achieved due to a more uniform distribution of oxygen concentration.

### 1. Introduction

Energy needs continue to increase due to technological developments and population growth, including electrical energy needs. At present various assistive devices lead to the use of electrical energy because it is easily obtained from various sources that are converted, easily stored and zero emissions. However, storing electrical energy in batteries still requires a relatively long recharging time and the battery is relatively heavier than the fuel with the same amount of energy. One solution to facilitate easier distribution of electrical energy is in the form of hydrogen energy [1].

Fuel cell technology can be used to convert hydrogen into electrical energy. Fuel cells convert hydrogen energy directly without combustion and without mechanical work so that it has a fairly high efficiency [2]. One type of fuel cell that can work optimally at a relatively low temperature is the Polymer Electrolyte Membrane Fuel Cell (PEMFC). Therefore, PEMFC is easily applied to portable electronic equipment and transportation equipment. Until now, the problem faced with the use of PEMFC is the price of MEA and bipolar plates which are still expensive. One way to reduce prices is by increasing PEMFC performance in the same MEA area [3].

One effective way to improve PEMFC performance is by modifying flow fields to be able to distribute reactants well [4,5]. Previous researchers have found that flow fields inspired by leaf shapes



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are superior to conventional flow field [6–9]. Some researchers use Murray theory to determine the channel width in the bio inspired flow field but there is no clear explanation on the thin channel.

## 2. Method

In this study we investigated the Polymer Electrolyte Membrane Fuel Cell (PEMFC) performance using numerical simulations. The model is composed of 9 layers [10] with 25 cm<sup>2</sup> of active area (Figure 1). Leaf shape biometric flow field are used at cathode side with variations of mother channel input width, that are: 1.6 mm; 3.8 mm (Figure 2); and 6 mm, by considering Murray's theory. Serpentine flow fields are used on the anode side. Cell performance is also compared with conventional parallel flow fields.

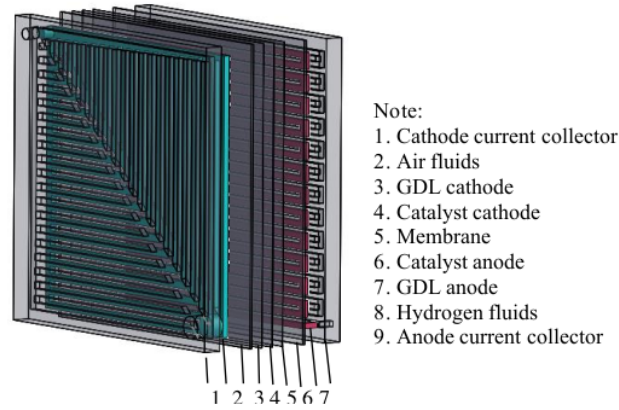


Figure 1. The model of 9 layers PEMFC.

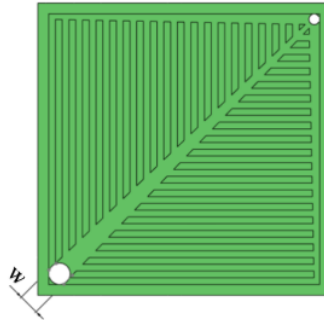


Figure 2. Leaf shape biometric flow field design.

The transport equation used is the following [10]:

$$\nabla \cdot (\rho \phi \vec{V}) = \nabla \cdot (\Gamma_{\phi} \nabla \phi) + S_{\phi} \quad (1)$$

where  $\rho$  is the mixture density,  $\vec{V}$  is velocity,  $\phi$  is the transported quantity (mass, momentum, energy),  $\Gamma_{\phi}$  is diffusivity, and  $S_{\phi}$  is the source term.

Electrical current at anode and cathode side,  $R_a$  and  $R_c$ , obtained from the Butler-Volmer equation [10]:

$$R_a = \zeta_a j_a^{ref} \left( \frac{[H_2]}{[H_2]_{ref}} \right)^{\gamma_a} \left( e^{\frac{\alpha_a F \eta_a}{RT}} - e^{-\frac{\alpha_c F \eta_a}{RT}} \right) \quad (2)$$

$$R_c = \zeta_c j_c^{ref} \left( \frac{[O_2]}{[O_2]_{ref}} \right)^{\gamma_c} \left( -e^{-\frac{\alpha_a F \eta_c}{RT}} + e^{-\frac{\alpha_c F \eta_c}{RT}} \right) \quad (3)$$

where  $\zeta$  is a specific active surface area,  $j_{ref}$  is reference exchange current density per active surface area,  $\alpha_a$  and  $\alpha_c$  are the anodes and cathode transfers coefficients,  $\gamma_a$  and  $\gamma_c$  are anode and cathode concentration exponents,  $\eta_a$  and  $\eta_c$  are the anode and cathode overpotentials, and  $V_{oc}$  is open circuit voltage.

The model is assumed to be a single phase laminar flow with a working temperature of 333 K and operating pressure of 1 atm. Hydrogen and oxygen flow mass as reactant gas are kept constant at  $6.10^{-7}$  kg.s<sup>-1</sup> and  $2.10^{-5}$  kg.s<sup>-1</sup>. The operating voltage is varied by 0.8 V; 0.6 V; 0.4 V; and 0.2 V. The detailed model parameters are shown in Table 1, which were based on several references [11].

**Table 1.** Model parameter.

| Property                            | Value                | Unit                                 |
|-------------------------------------|----------------------|--------------------------------------|
| Anode concentration exponent        | 1                    |                                      |
| Cathode concentration exponent      | 1                    |                                      |
| Open circuit voltage                | 1.05                 | V                                    |
| Anode Reference concentration       | 0.0008814            | kmol.m <sup>-3</sup>                 |
| Cathode Reference concentration     | 0.0008814            | kmol.m <sup>-3</sup>                 |
| Anode charge transfer coefficient   | 1                    |                                      |
| Anode reference current density     | 7.17                 | A.m <sup>-2</sup> . Pt <sup>-1</sup> |
| Cathode charge transfer coefficient | 1                    |                                      |
| Cathode reference current density   | 7.17x10 <sup>5</sup> | A.m <sup>-2</sup> . Pt <sup>-1</sup> |

In this study, Murray Law is used to calculate the width of the mother channel. The cross section of the mother channel on the input side is large and narrow at the end, adjusting the number of branches behind it. Determination of cross-sectional area based on equation (4) [6]:

$$d_m^3 = \Sigma d_d^3 \quad (4)$$

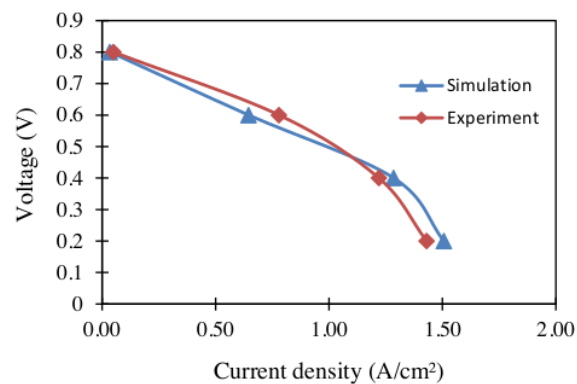
Where  $d_m$  is the hydraulic diameter of the mother channel and  $d_d$  is the hydraulic diameter of the daughter channel. In this study, the hydraulic diameter of the daughter channel was fixed with 1.25 mm width and 1 mm depth. The depth of the mother channel is also made 1 mm so that the hydraulic diameter of the mother channel only affects the width of the mother channel.

### 3. Result and discussion

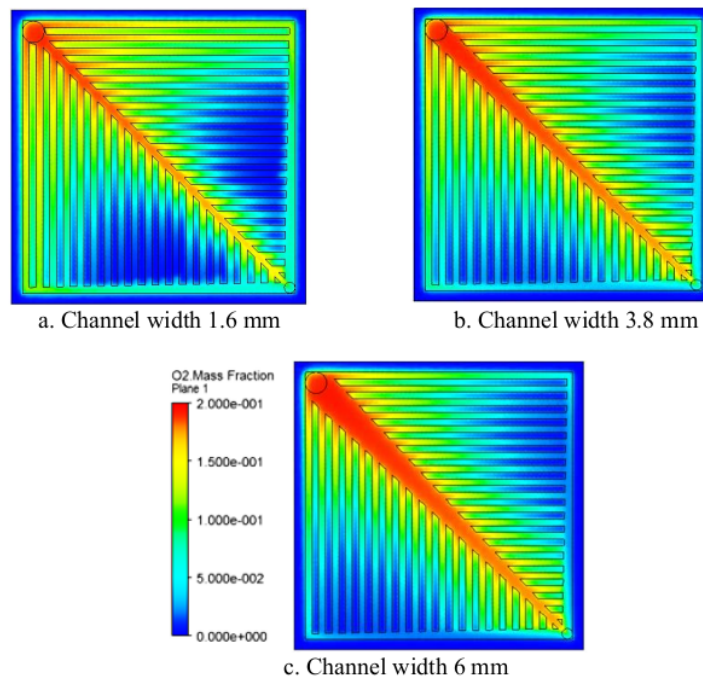
Comparisons were made to validate the simulation results with experiments conducted by Limjeerajaruus [11] in parallel flow fields. The results of the comparison are shown in Figure 3. In the experiment, the active area of 5 cm<sup>2</sup> was used so that just for the comparison simulation also used the same active area. In the broader active area of MEA, the channel gets longer so that the change in reactant concentration will be even greater. This will affect the current density and power density.

#### 3.1. Distribution of oxygen concentration with variation of mother channel width

In Figure 4 we can see that at 3.8 mm the mother channel width in the input section produces a more uniform distribution of oxygen concentrations than the 1.6 mm channel width or 6 mm channel width. At the 1.6 mm channel width, the mother channel that is too narrow causes oxygen to move sideways towards the branch channels at the front near the entrance. As a result, the branch channels behind it become deprived of oxygen. Whereas in the 6 mm channel width, the mother channel that is too wide causes oxygen to be less depressed to enter the branch channel. So that the end of the branch channel looks more dark blue when compared to the 3.8 mm channel width.



**Figure 3.** Validation of simulation results with experiments

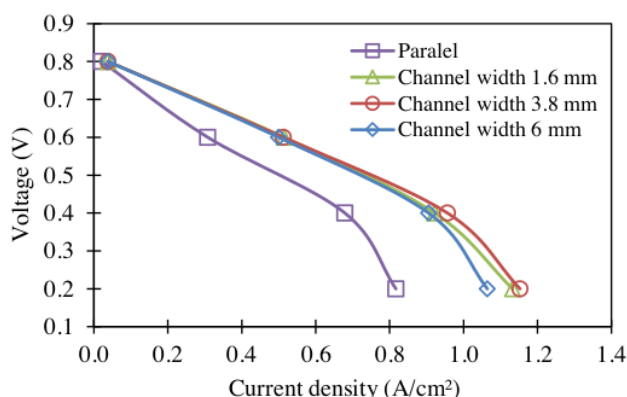


**Figure 4.** Distribution of oxygen concentration with variation of mother channel width.

### 3.2. Effect of mother channel width towards current density

From Figure 5 we can see that the 3.8 mm channel width produces the highest current density compared to other flow field variations. At 0.4 Volt voltage, 3.8 mm mother channel width produces current density  $0.96 \text{ A / cm}^2$ , 1.6 mm channel width produces  $0.92 \text{ A / cm}^2$ , and 6 mm channel width produces  $0.91 \text{ A / cm}^2$ , while parallel flow fields produce  $0.68 \text{ A / cm}^2$ . This shows that the optimal channel width

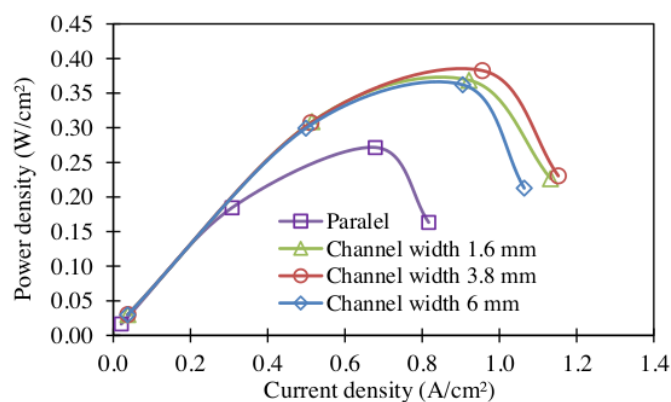
in leaf shape flow fields can increase current density up to 5.49%. This increase in current density is caused by an increase in the uniformity of oxygen distribution [4].



**Figure 5.** Graph of the effect of mother channel width towards current density.

### 3.3. Effect of mother channel width towards power density

From Figure 6 we can see that 3.8 mm channel width produces the highest power density compared to other variations. At 0.4 volts, 3.8 mm channel width produces 0.38 Watts, 1.6 mm channel width produces a current density of 0.37 Watts, and a 6 mm channel width produces 0.36 Watts. This shows that the optimal use of channel width will increase power density to 5.55%. Similar to current density, the increase in power density is caused by an increase in the uniformity of oxygen concentration at the cathode side so that the reactant supply is more guaranteed in each position [4,8].



**Figure 6.** Graph of the effect of mother channel width towards current density.

## 4. Conclusion

Based on the previous discussion, we can conclude that the optimal use of channel width on the input side of the mother channel will increase current density and power density by 5.49% and 5.55%. This is caused by an increase in the uniformity of oxygen concentration at the cathode side so that oxygen supply is more assured.



### Acknowledgement

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### References

- [1] C E Thomas 2009 Fuel cell and battery electric vehicles compared *Int. J. Hydrogen Energy* **34** 6005–20
- [2] S Hanapi, A Salami, A H A Rahim and W A N Wan 2015 *Comparison of A Prototype PEM Fuel Cell Powertrain Power Demand and Hydrogen Consumption Based on Inertia Dynamometer and On-Road Tests* **79** (Elsevier B.V.)
- [3] Y Wang, J Mishler and X C Adroher 2011 A review of polymer electrolyte membrane fuel cells : Technology, applications, and needs on fundamental research *Appl. Energy* **88** 981–1007
- [4] A P Manso, F F Marzo, J Barranco, X Garikano and M G Mujika 2012 Influence of geometric parameters of the flow fields on the performance of a PEM fuel cell. A review *Int. J. Hydrogen Energy* **37** 15256–87
- [5] A Fahrudin, D Ichsan and F Taufany 2018 Improving PEM fuel cell performance using in-line triangular baffles in triple serpentine flow field *MATEC Web Conf.* **197** 8010
- [6] A Ozden, M Ercelik, D Ouellette and C O Colpan 2017 Designing, modeling, and performance investigation of bio-inspired flow field based DMFCs *Int. J. Hydrogen Energy* **42** 21546–58
- [7] J P Kloess, X Wang, J Liu, Z Shi and L Guessous 2009 Investigation of bio-inspired flow channel designs for bipolar plates in proton exchange membrane fuel cells *J. Power Source* **188** 132–40
- [8] R Roshandel, F Arbabi and G K Moghaddam 2012 Simulation of an innovative flow-field design based on a bio inspired pattern for PEM fuel cells *Renew. Energy* **41** 86–95
- [9] N Guo, M C Leu and U O Koylu 2014 Bio-inspired flow field designs for polymer electrolyte membrane fuel cells *Int. J. Hydrogen Energy* **39** 21185–95
- [10] H Heidary, M J Kermani, A K Prasad, S G Advani and B Dabir 2016 Numerical modelling of in-line and staggered blockages in parallel flowfield channels of PEM fuel cells *Int. J. Hydrogen Energy* **42** 2265–77
- [11] N Limjeeararus and P Charoen-amornkitt 2015 Effect of different flow field designs and number of channels on performance of a small PEFC *Int. J. Hydrogen Energy* **40** 7144–58



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