Simulation and Experimental Study of Bipolar Plate on the Performance PEM Fuel cell

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Abstract. This research is a simulated and experimental study on effects of bipolar electrodes of a PEM fuel cell on its power conversion efficiency. The PEM fuel cell structure consists of bipolar electrodes, proton exchange membrane with catalysts, flow channels of gases. This research used fuel cell of 49 cm^2 in active area as a research sample and the Comsol 4.4 was employed to simulate flow channels which are serpentine pattern for anode and parallel pattern for cathode. The parameters used were calculated effects of such parameters using Comsol 4.4. After the calculation has been completed, the prototype of the PEM fuel cell were fabricated using graphite plate as electrodes which had the channel height of 0.20 cm, proton exchange membrane using carbon-platinum catalyst. Finally, further it was found that the effect of temperature on the power conversion efficiency is not severely. And for anode, the concentration of hydrogen gas was reduced 64 wt% due to the reaction whereas in parallel channel of cathode the oxygen concentration was reduced by only 6 wt% from 23 wt% at the entrance to 17 wt% at the end. The maximum power output of the prototype operated under such condition was 0.28 W/cm^2 calculated from maximum power output voltage (Vmp) of 0.70 V and maximum power output current density of 0.42 A/cm^2 which was in good agreement with that simulated using Comsol 4.4 which revealed the power output of 0.29 W/cm^2.

1. Introduction

Proton exchange membrane fuel cells (PEMFC) are regarded as the most promising alternative power source due to the advantages of high power density, low operating temperature, easy implementation, etc. By over %60 of the weight and 30% of the total cost, bipolar plate (BPP) is one of the key components of PEMFC. Moreover, because of the existence of flow field on the BPP, plays an essential role in fuel cell from the perspective of fluid dynamic. A number of researches on channel designs are being conducted to find more effective fuel and oxygen supply methods, especially in the flow fields. Graphite-based BPP has been studied and applied widely due to its low interfacial contact resistance and high corrosion resistance.[1] Estimated that the bipolar plates account for about 40% of the total cost and 40% of the mass of the stack. Numerical analysis is a vital role in the study of fuel cells because it can measure momentum, heat transfers and mass transfers of fuel cells, which cannot be measured in experiments. First, [2] showed the improved performances of the integrated flow fields and the serpentine flow fields by forced convection. When the reaction surface in the channels was increased, but the performance of the parallel flow fields was reduced due to low oxygen supply. [3] Compared current densities temperatures, and the water content distributions of membranes of serpentine flow fields for the same reaction surface according to the numbers, the lengths and the designs of channels using numerical analysis. [4] Applied biological flow fields patterns of leaves to parallel flow fields based on the facts derived through numerical analyses. That is, the performances of flow fields varied depending on the design, size and pattern of the flow fields. The results showed that the power density was improved by 56% compared to the parallel flow fields and by 26% compared to the serpentine flow fields. [5,6] Used a non-dimensional variable to predict flooding in the cathode and suggested a channel that used the Concuse Finn phenomenon to effectively remove flooding. From the perspective of flow field design, the primary requirement is to obtain uniform distribution of the reactant gases over the respective active electrode surface the concentration over potential. Based on this requirement, an analytical model and numerical simulation are usually adopted for the flow field design due to lower cost and higher efficiency. With analogy between the gas pressure and the electric voltage, the gas flow and electric current, an electric circuit analogy used in analyzing the flow distribution. This study suggests the design flow fields, by forced convection of this method by evaluating the performance of PEM fuel cell. This study provides the design factors and performance of the PEM fuel cell as information for determining the optimized design of the anode channel and cathode channel of the PEM fuel cell. The purpose of this study is to suggest contemporary alternatives to reduce the concentration loss. For this reason, we were examined according to the variations of the heights and the distances of variations induced by the suppression of concentration loss. We fabricated the optimized channel, which was verified by simulation and an experiment, as a unit cell of the PEM fuel cell to compare the performance of the optimized channel with those of other channels.

2. Materials and Methods Associated theories

2.1 Schematic diagram of methodology

The computational simulation show that the average values of stresses in fuel cell are the same as those of the secondary current distribution and reacting flow in porous media model. The method summarized in **Fig. 1**

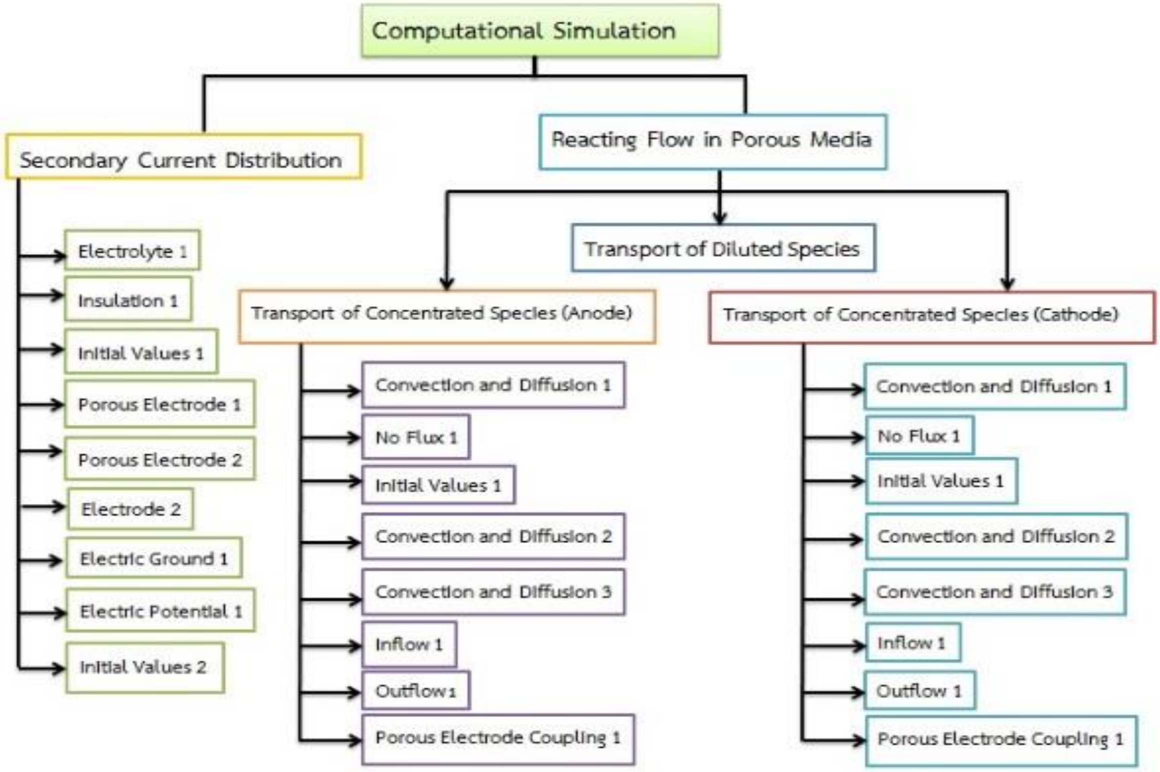


Fig. 1 Schematic diagram of methodology

Conditions for single-cell numerical analysis

Numerical analysis of a single-cell was first performed before the flow field was analyzed to evaluate the effects of the wave-form shape. The results were compared to the references. The sizes of the channel were calculated from the straight sections of the 49 cm^2 unit cell channel. The width of the cathode was 5.0 mm and its length was 1 mm. The width of anode was 5.0 mm and its length was 6.0 mm. The ribs were structured every 5.0 mm on both sides of the channels. The thickness of the gas diffusion layers was 2.0 mm, that of the catalyst layers was 2.0 mm and that of the membranes was 05.0 mm. **Table 1** shows the parameters in PEMFC module. The analyses were performed according to the changes in the fluid flows of the cathode and the anode.

Table 1- Physical Parameters in a PEMFC model.		**Table 1- Physical Parameters in a PEMFC model.** (Continuous)	
Parameter	Expression	Inlet H_2O mass fraction (cathode)	0.023
Channel height	2 mm	Inlet oxygen mass fraction (cathode)	0.228
Channel width	5 mm	Anode inlet flow velocity	0.4[m/s]
GDL porosity	0.4	Cathode inlet flow velocity	0.4[m/s]
GDL permeability	1.18e-11[m^2]	Cell temperature	323[K],333 [K] and 343[K]
GDL electric conductivity	222[S/m]	Cell voltage	0.9
Inlet H_2 mass fraction (anode)	0.743	Anode pressure and Cathode pressure	0.5[atm],1[atm] and 1.5[atm]

2.3 Fabrication a simulation bipolar plate with comsol 4.4

Fig. 2 shows the results from a simulation created by making the design characteristics of gas flow channel plate, bringing a bipolar plate with comsol 4.4 two types is serpentine anode side and parallel cathode side.

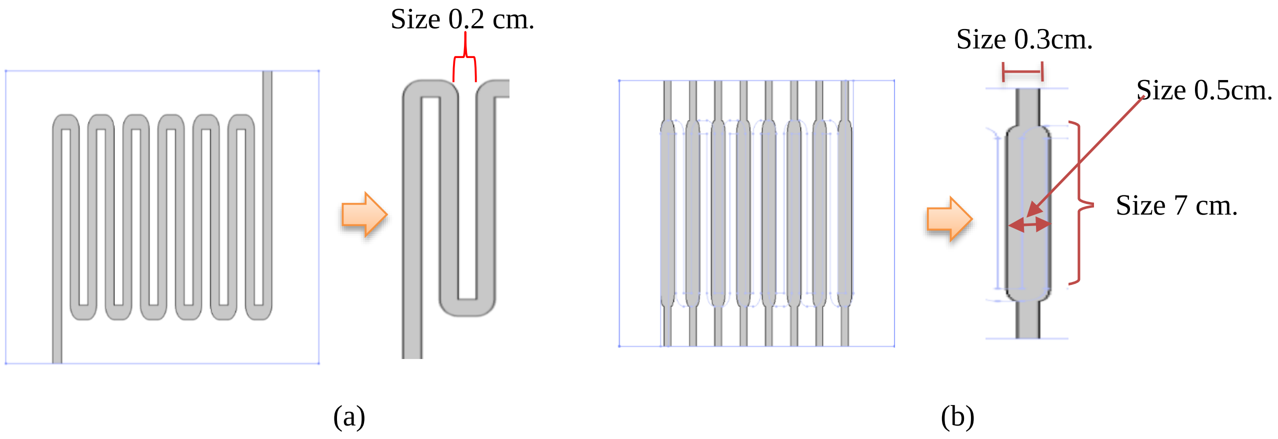
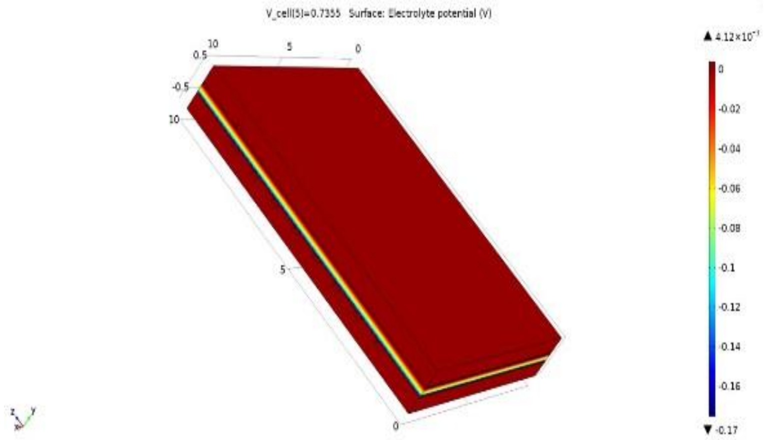


Fig.2 Showed Characteristics of gas flow channel on the bipolar plate, (a) Anode side (serpentine) and (b) Cathode side (parallel)

3. Results and Discussion

3.1 Effect of electrolyte potential



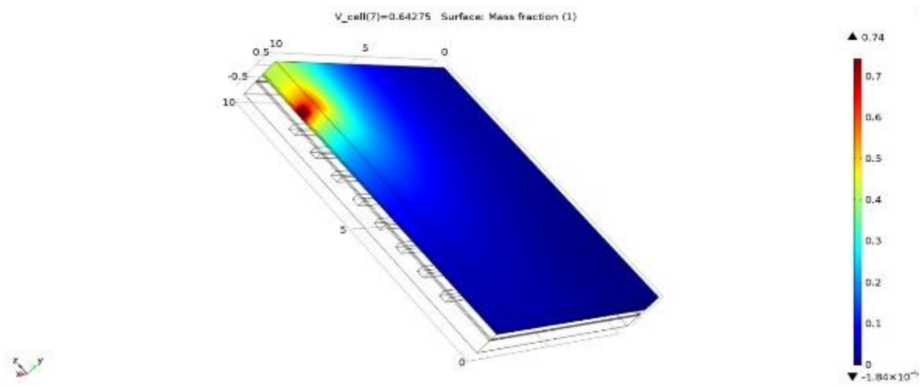
(a) **(b)**

Fig.3 a) Showed effect of electrolyte potential, b) Showed effect of level conduction

Fig. 3 illustrate the effect of the density of the electrical current in the simulation. From a show that is a red area will have many effects on electric current capacity of thickness, which is the area is a two-pole electric current sheet, which is caused by oxidation in the anode side of a moving electric current within the bipolar plate and in the middle of the area in yellow, green and blue electrical insulation which is membrane area. Which feature of this membrane will allow protons moving through but not allow electrons to pass through. By the relationship between the motion of electric charges, and over potential can be described by an equation involving kinetic energy equation an equation that is Butler-Volmer and Tafel.

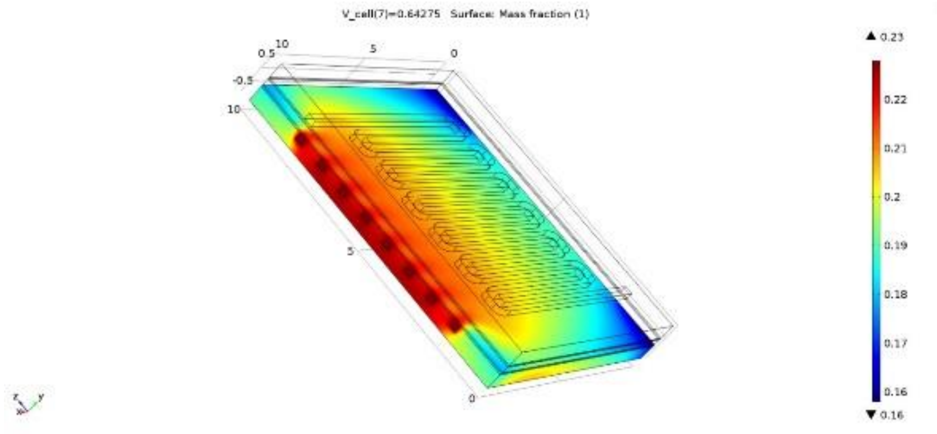
3.2 Effect of mass fraction

The result of the movement of a substance (Mass Fraction) in the model, size, the depth of the channel, the flow of gas, gas pressure fuel cells is to 1.0 atm temperature 50° c, flow rate of fuel 150 sccm and 100 %RH, when considering the concentration of gas inside the gas flow channel on both the anode and cathode, resulting from chemical reactions, electrical. Which results in the movement of a substance (Mass Fraction) anode in Figure 4 and displays the results in the picture at the cathode in Figure 6.



(a) **(b)**

Fig.4 a) Showed effect of mass faction in side anode, b) Showed effect of level distribution concentration in side anode



(a) **(b)**

Fig.5 a) Showed effect of mass faction in side cathode, b) Showed effect of level distribution concentration in side cathode

From Figure. 4 considering that the area is red, there will be a concentration of hydrogen gases accumulate so much, because it is a gas at the entrance of hydrogen. When gas hydrogen moves into the gas flow can occur, the proton and electron in the catalyst layer. It can be seen that in the first stage will result in better reaction and then the quantity of hydrogen gas, the concentration it will gradually decrease observed from the area of yellow, green and blue, and then the hydrogen gas is dispersed throughout a gas flow across the channel, which will be determined from the blue area. When the idea of the hydrogen gas, the consumption in proportion by mass. Gas, the arrivals' area is equal to 74 percent and 10 percent of the departures' area so it has a concentration of gases decreased 64 percent by mass. From Figure. 5 consider the red area is the area of the oxygen it can be seen that the range entrance is the concentration of oxygen is the most. The concentration of oxygen at the cathode electrodes are concentrations decreased gradually throughout the gas flow channel. Consider it from yellow-green areas. Blue and dark blue because the concentration of oxygen used in the reaction causes the product which is water (H_2O), hydrogen gas will be less than the rate and quality of the entrance channel, the flow of gas, the oxygen will be used the most. By thinking of oxygen consumption in the proportion, by mass. Gas, the arrivals' area is equal to 23 percent and 16 percent of the departures' area, which happens to be a phenomenon according to the equation. Navier – Stokes equations and Brinkmun.

3.3 Performance of PEMFC for experimental and simulation

Figure. 6 shows the initial performance of the single cells with two different performance. The performances of the fuel cell using expanded for experimental is slightly lower than the performance of fuel cell using simulation. This phenomenon can be explained by the higher contact resistance of the expanded simulation. The performance of experimental fuel cell is the same as that of expanded simulation.

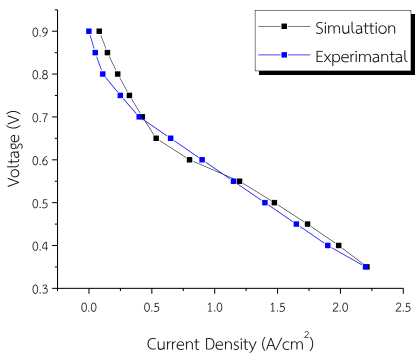


Fig.6 comparison of polarization curve for Simulation and Experiment

4. Conclusions

This study Performance of PEMFC for experimental and simulation. The results were compared to the references. The sizes of the channel were calculated from the straight sections of the 25 unit cell channel. And for anode, the concentration of hydrogen gas was reduced 64 wt% due to the reaction whereas in parallel channel of cathode the oxygen concentration was reduced by only 6 wt% from 23 wt% at the entrance to 17 wt% at the end. The maximum power output of the prototype operated under such condition was 0.28 W/cm^2 calculated from maximum power output voltage (Vmp) of 0.70 V and maximum power output current density of 0.42 A/cm^2 which was in good agreement with that simulated using Comsol 4.4 which revealed the power output of 0.29 W/cm^2. This study performance of PEMFC for experiment and simulation the performance of experimental fuel cell is the same as that of expanded simulation.

5. Acknowledgments

This work was supported by program in of Physics, Faculty of Science and Technology, program in of Physics, Faculty of Education Rajabhat Mahasarakham University and the authors thank the of department of Physics, Faculty of Science Khon Kaen University for their support.

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