500W급 공냉식 고분자 연료전지 설계, 제작 및 운전 특성

The Analysis of the Operating Characteristics In A 500W Portable Air Cooled Polymer Electrolyte Membrane Fuel Cell (PEMFC)

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ABSTRACT

To maintain proper operating conditions is important to get optimal output power of a PEMFC stack. The air cooled fuel cell stack is widely used in sub kW PEMFC systems. A 500W air cooled PEMFC stack was experimentally investigated to evaluate the design performance and to get optimal operating conditions for the portable application. The relationship between the operating conditions and the performance was analyzed. The results can be used as design criteria for portable PEMFC under various conditions.

1. INTRODUCTION

In many application of PEMFC, portable power module should be operated under the one of the most various environments because it can be movable. The power and performance of the fuel cell system can be changed with the ambient humidity and temperature. The portable power system should be able to adapt to these environments by itself through the water and heat balance of the system.

The power of the PEMFC is closely dependent on the relative humidity of the reactant air in the stack. The relative humidity is determined by the humidity and temperature of the input reactant air and the stack. The air cooled fuel cell stack is broadly applied in sub kW PEM fuel cell system. However, as the power density of stack is increased, it is harder to get enough balanced humidity of input fuel air and stack cooling by ambient air. To design portable power fuel cell system, it is crucial to know the boundary of possible operating input fuel air humidity and controllable air cooled stack temperature to maintain stable and high power output.

There were many researches about the water and heat balance of PEMFC or DMFC (Ahmed, S et al. 2002, Michael, G. Izenson et al. 2003). However, it is hard to find the data that was carried out with the real hundreds W PEMFC adapted air cooling system.

Water balance is coupled phenomena with water produce in the MEA, stack temperature and fuel air humidity. Therefore, parametric experiment with real system is useful approach. This paper is focused to get the relationship between the power of the stack and the relative humidity through the control of the air cooling system.

2. TEST APPARATUS AND EXPERIMENT MODEL

The stack (figure 1) was consisted with 16 cells that part from each other by the corrugulated plates for forced air cooling. The active area of the each cell was $100cm^2$. The four axial fans control the stack temperature. K type thermocouples were used to get the temperature data at the four location of the stack.

Figure 2 shows the schematic diagram of the experiment. The reactant air was humidified 100% through the heated water reservoir that was controlled at the setting temperature. The temperature of water reservoir was set 30, 40 and 50℃ according to the capacity of the possible heat and water exchanger. The stack temperature was controlled by four axial fans to reflect the real system control condition. Therefore, there was some variation of the stack temperature as the current of the stack was modified from low to high although the temperature was 60℃ as stable as possible. The relative humidity can be calculated by the following equation (James Larminie et al.).

$$\Phi = P_w/P_{sat}$$

P_w and P_{sat} is the saturated vapor pressure at the reactant air inlet and the stack temperature respectively. The tube which was connected from the water reservoir to the reactant air inlet kept isothermal state by the insulating material. The temperature deviation between the water reservoir and the reactant air inlet was 2 or 3 degree. Therefore, it can be assume that the temperature for the P_w was the one of the reactant air inlet. The stack temperature was varied with the current as above mentioned, the relative humidity also have some deviation. Therefore the three case of the relative humidity was compared by the average value.

3. RESULTS AND DISCUSSION

3-1. The voltage, current and power of the stack

The relative humidity was calculated at the each temperature setting.

Φ_{avg_30} = 37%, Φ_{avg_40} = 48% and Φ_{avg_50} = 66%

at the temperature set value of the water reservoir was 30, 40 and 50℃ respectively.

Figure 3 shows the voltage/current and the power/current graph at the each case. The relative humidity at the reactant air inlet is the higher, the voltage and power of the stack is the better. This pattern of the voltage is presented clearly at the low and high of the current. The power of the stack is different from each other at the high current region and the deviation is up to 70W at the 0.5~0.6kW region. Although the power and voltage is slightly different from each other at the rate voltage, 9.6V, this deviation of the power at the maximum region can be crucial when the application load needs high power such as the starting point or sudden action.

3-2. Cell voltage distribution and relative humidity

Figure 4~6 shows the average cell voltage and the deviation of the maximum and minimum at the each relative humidity cases. The deviation of the cell voltages is considerable at the high current operation for all cases. The amount of water is more produced at the high current operating region. Therefore, the exhausting condition of water can be more complicated in the flow channel of the separated plates. As a result, it is the one of the reasons that this complex condition drives the notable difference of each cell. Moreover, the 66% relative humidity case shows more various differences at the broad operating region. The result indicates that water balance can be hard to keep above 70% relative humidity although the stack produces the more power.

3-3. 500W operating results by air cooling PEMFC stack

Figure 7 shows the operating data. The relative humidity keeps about 64% in the stable operating region. The data is selected in the above operating case, figure 7.

4. CONCLUSIONS

The PEMFC stack was designed and manufactured with 16 cells that had 100cm^2 active area. The experiment of the stack was carried out at the three relative humidity condition controlled by the temperature of the stack and the inlet reactant air. Air cooling method was used to control the temperature of the stack.

The difference of the stack power was up to 70W in the 500~600W operating region between 37% and 66% relative humidity. The stack voltage was diverged at the low and high current operating region.

The stack power is more improved at the 66% relative humidity case than compared to other cases. However, water production also increased and cell voltage was more unstable.

The air cooled PEMFC stack that was designed for 500W optimal operating worked successfully at the 60% range of the relative humidity.

REFERENCES

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James Larminie and Andrew Dicks, *Fuel Cell Systems Explained*, 2nd ed.

Michael, G. Izenson and Roger, W. Hill, 2003, Water and Thermal Balance in PEM Fuel Cells, *the first international conference on fuel cell science, engineering and technology*, pp. 477-48

FIGURES

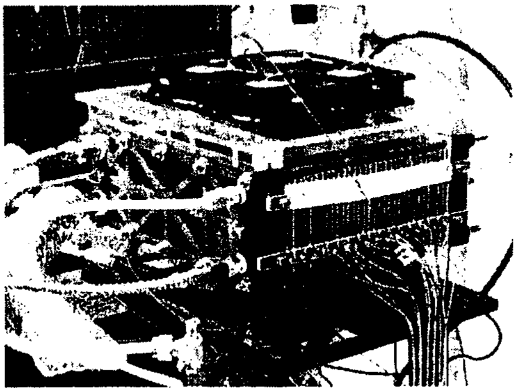

Fig. 1 The picture of the experimented PEMFC stack

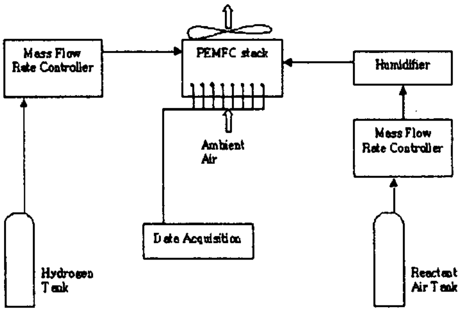

Fig. 2 The schematic diagram of the PEMFC experiment system

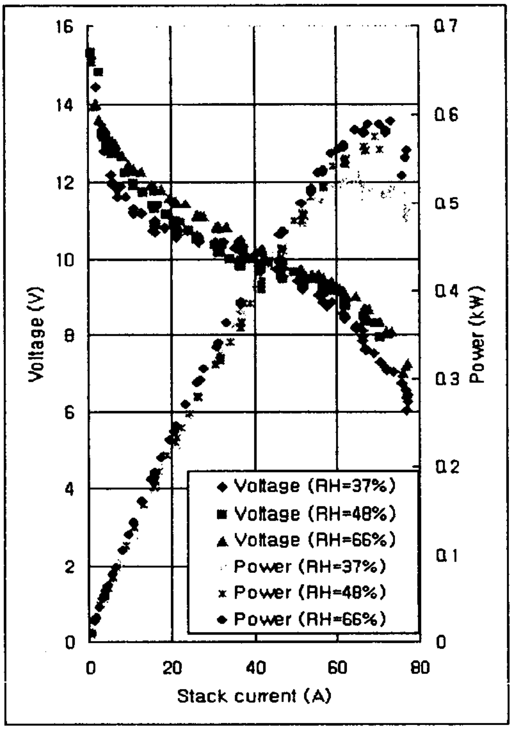

Fig. 3 the voltage/current and the power/current graph at each relative humidity (RH) cases

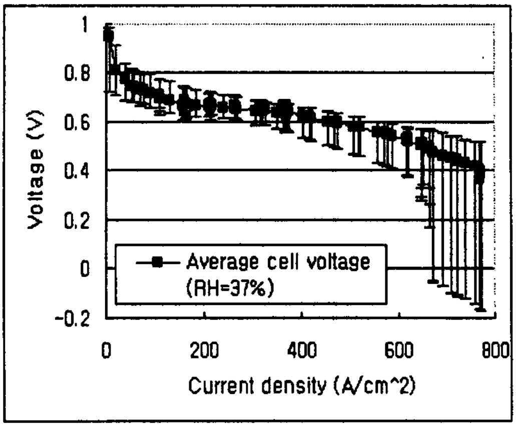

Fig. 4 The average and the distribution of cell voltage at the 37% relative humidity

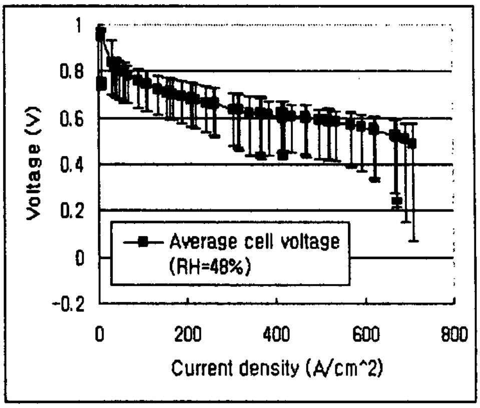

Fig. 5 The average and the distribution of cell voltage at the 48% relative humidity

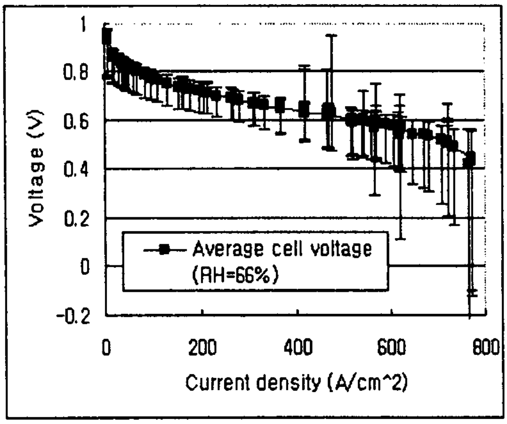

Fig. 6 The average and the distribution of cell voltage at the 66% relative humidity

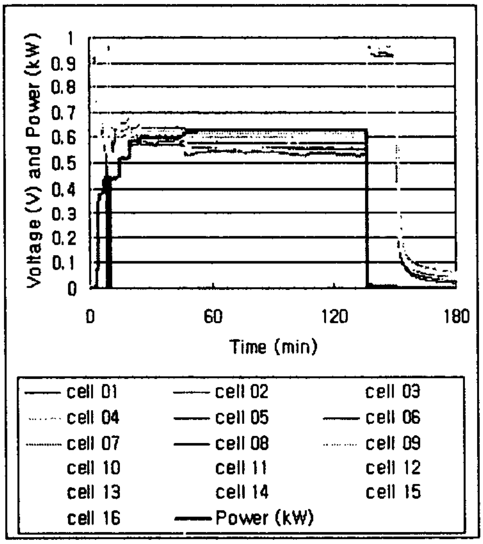

Fig. 7 The voltage of the cells and the stack power graph