F-11

연료전지/배터리 하이브리드 차량 개발

Development of Fuel Cell/Battery Hybrid Vehicle

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ABSTRACT

Fuel cell systems are consisted of various parts, for example fuel cell stack, fuel supplier, electrical converters, controllers and so on. Each components of system should have appropriate specification for their applications as well as simplicity. Because thermal load can be managed simply by using fans without any water cooling system, the air-cooled PEMFC is widely used in sub kW and around 1kW systems. The performance of an air-cooled system is highly dependent on ambient temperature and humidity. In this paper, the air-cooled PEMFC systems are developed and investigated to study the operating characteristics in the aspect of the thermal and water coupled management by the control ofthe axial fans and compressors. Various experiments were also conducted to get the cell voltage distribution, the relative humidity of the reactant gas and the thermal management by axial cooling fans, which cannot be observed in single cell experiment. After then, as practical applications, portable fuel cell system and a hybrid electric cart were successfully integrated and operated by using this air-cooled stack.

1. INTRODUCTION

Design of fuel cell stack is highly complicated. A lot of parameters affect the performance of system and these parameters are tightly related each other. Contrary to single cell, stack must be considered manifold design to well distribute flow rate at each cell. Pressure drop is also important to operate complete system with air compressor.

When it comes to operating fuel cell stack, in many application of polymer electrolyte membrane fuel cell (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 because of simple and easy method. 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.

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 also focused to get the relationship between the power of the stack and the relative humidity through the control of the air-cooled system.

2. TEST APPARATUS AND EXPERIMENT MODEL

The stack (figure 1) was consisted with 16cells and 52cells that part from each other by the cooling fins for forced air cooling. The active area of the each cell was 100cm2. The several 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. Thetemperature of water reservoir was set 30, 40 and 50C 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 60C as stable as possible. The relative humidity can be calculated by the following [1].

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

Pw and Psat 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 Pw 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

Considering the general relation of several parameter, the more relative humidity increases, the more ion conductivity of membrane improves but the deactivated area of catalyst layer also enlarges because water flooding appears in the channels. Therefore the uniformity of each cell's voltage or the stability of stack performance can be deteriorated under low as well as high relative humidity. Moreover, MEA is optimised for gas and water transport in specific condition by treatment of PTFE at the gas diffusion layer and design of the structure of micro layer. As a result of the MEA specification, the operating condition can be restricted for getting appropriate cell voltage and performance [2]. In addition, humidifier of air has tobe limited for the application of portable power system. With these circumstances in mind, it is important that determine the proper relative humidity within the designed parameters such as the pressure drop through the channel, MEA property, performance of humidifier and cooling fans and so forth.

Figure 3 shows the average cell voltage and the deviation of the maximum and minimum at the each relative humidity cases. In the 37% relative humidity case, minimum voltage steeply decreases above 550mA/cm2 region although the average voltage still have moderate value. On the contrary, the I-V performance and the deviation between minimum and maximum voltage of the other cases appear acceptable. This result indicates two facts. The one is that designed pressure drop is enough to elucidate water in the channel under 50% ~ 70% relative humidity condition. The other is that low relative humidity can be dominant reason of cell voltage distribution instability caused by the deterioration of ion conductivity. As a result, about 65% relative humidity operating condition is proper if this condition is controllable by humidifier and axial fans.

It is important that the voltage of each cell keep uniform at various current levels. The cell voltage distribution of 21-cell stack at three selected points is shown in figure 4. Average cell temperature is 60C and air input temperature is 50C. Air stoichiometry is 2.3. Point 1, 2 and 3 indicate the voltage variation at open circuit voltage, normal power output and 0.6 average voltage points respectively. The uniformity of cell voltages is acceptable, despite the fact that the voltage of 2 or 3 cells where are the opposite from manifold inlet appears over 18% lower then average voltage at above region of current density

550mA/cm2.

The parasitic load associated with the forced cooling by axial fans also is shown at figure 5. The operation is carried out under the identical condition of figure 4. Ambient temperature is typical room value, 20℃. As shown in the graph, the heat control of the PEMFC stack is successfully carried out by axial fans under the 2% consumption of power compared to the total power output of the stack.

52cell stack is developed from the study based on the above. The incipient operating performance data is shown in figure 6. The power indicates about 1.2kW at nominal voltage (point 2). The stack has 1.8kW maximum power in the experiment (point 4).

Portable fuel cell system and fuel cell hybrid vehicle are developed from the air-cooled fuel cell stack (Figure 7).

4. CONCLUSIONS

The PEMFC stack was designed and manufactured with 16 cells that had 100cm2 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 stack voltage was diverged at the low and high current operating region in the case of 37% relative humidity. The stack power is more improved at the 66% relative humidity case than compared to other cases.

The air-cooled PEMFC stack that was designed for 500W and 1.6kW optimal operating workedsuccessfully at the 60% range of the relative humidity.

REFERENCES

[1] James Larminie and Andrew Dicks, Fuel Cell Systems Explained, Second ed., John Wiley & Sons Ltd, England, 2000

[2] Gu-Gon Park, Young-Jun Sohn, Tae-Hyun Yang, Young-Gi Yoon, Won-Yong Lee, Chang-Soo Kim, Journal of Power Sources, 131 (2004) 182-187

FIGURES

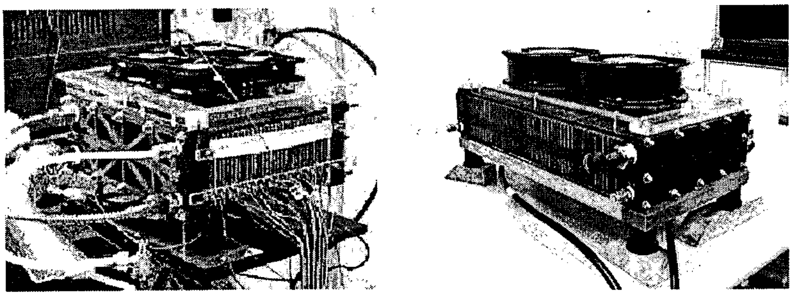


Fig. 1. The picture of experimented PEMFC stacks (16cells: left, 52cells: right)

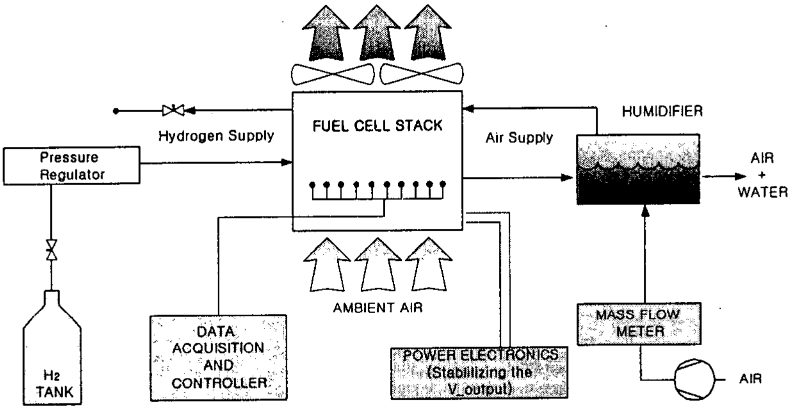
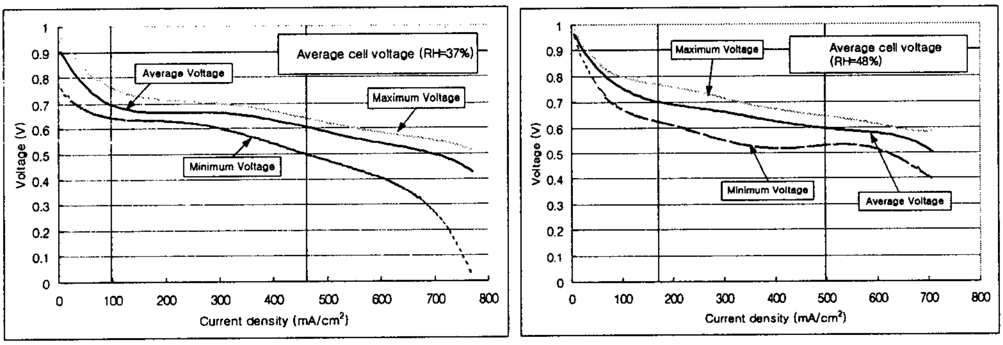
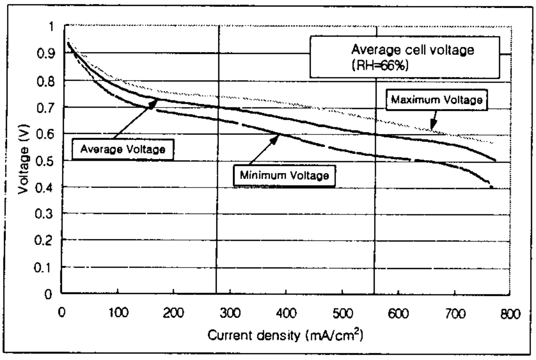


Fig. 2. The schematic diagram of the PEMFC experiment



(a) relative humidity = 37% (b) relative humidity = 48%

Fig. 3. The average and the distribution of cell voltage with respect to the relative humidity



(c) relative humidity = 66%

Fig. 3. The average and the distribution of cell voltage with respect to the relative humidity

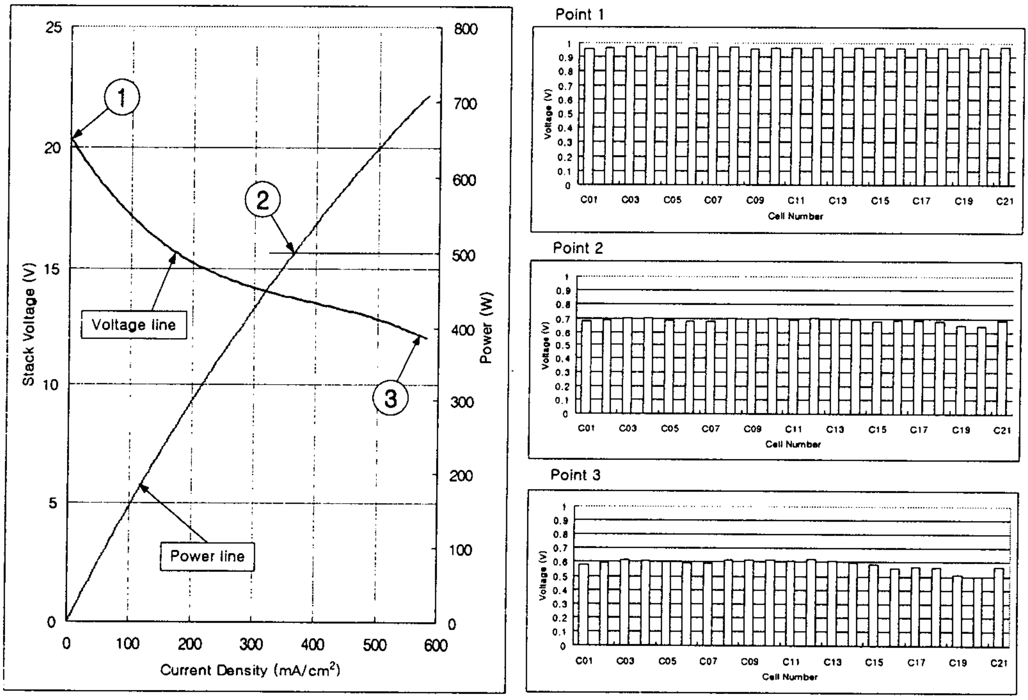


Fig. 4. I-V performance curve of 21-cell stack and voltage distribution at various current levels

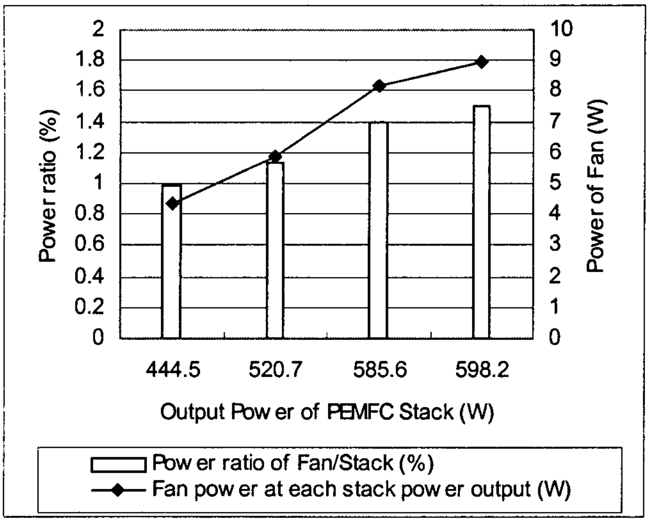


Fig. 5. The parasitic load associated with the forced cooling by axial fans

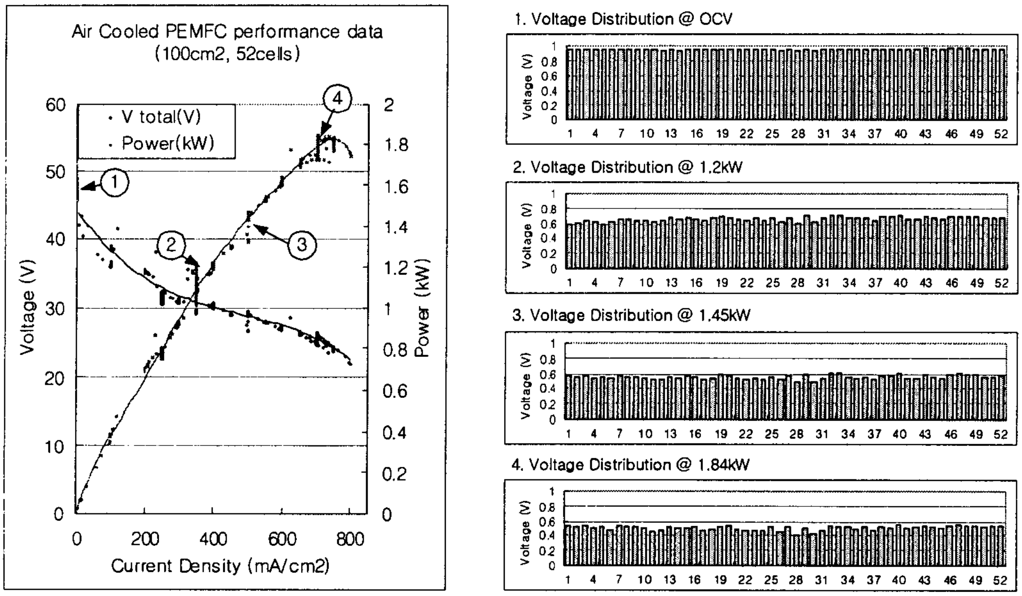
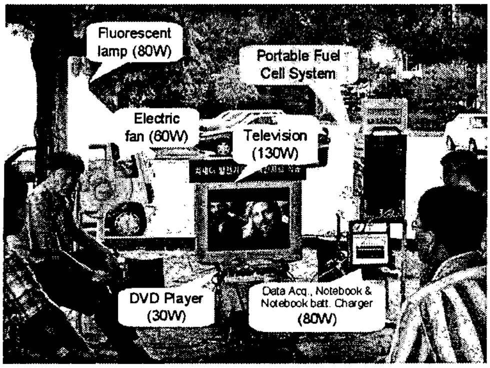
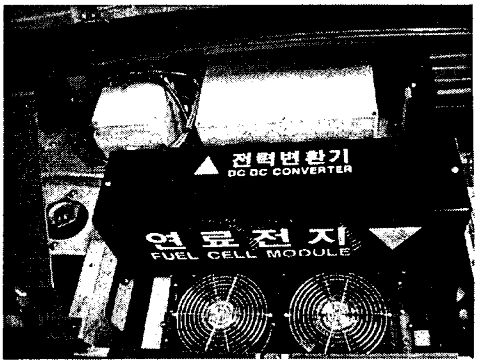


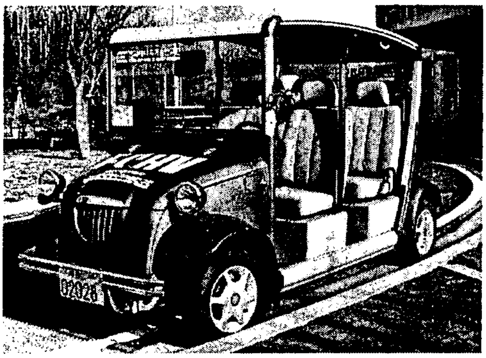
Fig. 6. I-V performance curve of 52-cell stack and voltage distribution at various current levels.





(a) portable system demonstration (b) fuel cell module of FCV

Fig. 7. Applications and demonstrations of Air-cooled fuel cell in KIER



(c) KIER fuel cell vehicle

Fig. 7. Applications and demonstrations of Air-cooled fuel cell in KIER