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Analysis of water and thermal management with coolant operating conditions for a proton exchange membrane fuel cell

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ABSTRACT

A coolant operating condition in a fuel cell stack is an important factor to determine the temperature distribution which affects a fuel cell performance and relative humidity at its inside. In this study, the effect of the coolant operating condition on the performance of the fuel cell stack was investigated with relative humidity at the H_2 inlet. For relative humidity values at the H_2 inlet of 0%, 50% and 100%, tests were conducted with the coolant flow rate of 0.1–0.8 l/min cell and the coolant inlet temperature of 20–82 °C. The coolant inlet temperature had a proper range to maintain the optimal cell voltage. The proper range of coolant inlet temperature increased with increasing the coolant flow rate and relative humidity at the H_2 inlet. When considering the optimal voltage efficiency, the relative humidity at the H_2 inlet of 50% was comparatively the optimum condition. Then the heat removal rate was 0.40–0.65 W/cm^2 cell.

1. Introduction

A proton exchange membrane (PEM) fuel cell is generating reaction heat during producing electric power through electrochemical reactions. The generated heat elevates the temperature of the fuel cell stack to the proper reaction temperature, but overheating the cell causes drying of the membrane and decreases its electric conductivity. To maintain a desired temperature, the heat generated by the electrochemical reactions has to be removed from the fuel cell stack [1–3].

However, experimental studies on the coolant operating conditions required to effectively removal heat from a fuel cell have been insufficient and little experimental work has been done to determine the combined effect of coolant controls and humidification on the fuel cell performance. Thus, in this study, the performance of a fuel cell stack was experimentally evaluated with the coolant inlet temperature and flow rate for the relative humidity at the H_2 inlet of 0%, 50% and 100% so that the proper coolant operating condition was determined for obtaining the optimal performance of the fuel cell stack. Additionally, the heat removal rate by the coolant from the fuel cell stack was compared with the performance. So we suggested a proper range of the heat removal rate and coolant operating conditions to maintain the optimal performance of the fuel cell stack.

2. Experimental set-up

Fig. 1 shows a schematic diagram of the test apparatus used to evaluate the performance of a fuel cell stack. Gore 57 Series MEAs were used to make the stack and the reaction areas of the cells were 200 cm^2. The input power of a water pump was controlled in order to adjust the coolant flow rate. A line heater and a radiator were set to control the coolant inlet temperature. We referred to the Ref. [4] for making the humidification system. Thermocouples, humidity sensors and pressure transducers were installed inside the inlet and outlet of the reactants and the coolant.

In this study, tests were conducted with the constant flow rate on H_2 and air stoichiometry ratio of 1.5 and 2.5, respectively, and the inlet temperatures of the reactants were fixed at 60 °C. The fuel cell stack was operated in constant current mode at 0.7 A/cm^2. To investigate the performance of the PEMFC with the coolant operating conditions, the relative humidity at H_2 inlet was set to 0%, 50% and 100%, while the relative humidity at cathode inlet was fixed at 100%. Tests were conducted with the coolant flow rate of 0.1–0.8 l/min cell and the coolant inlet temperature of 20–82 °C. The data were recorded for 10 min after reaching a steady state for each test condition.

3. Results and discussion

3.1. Performance of the fuel cell stack

Fig. 2 shows cell voltage according to the coolant inlet temperature and flow rate when the relative humidity at the H_2 inlet is 0%,

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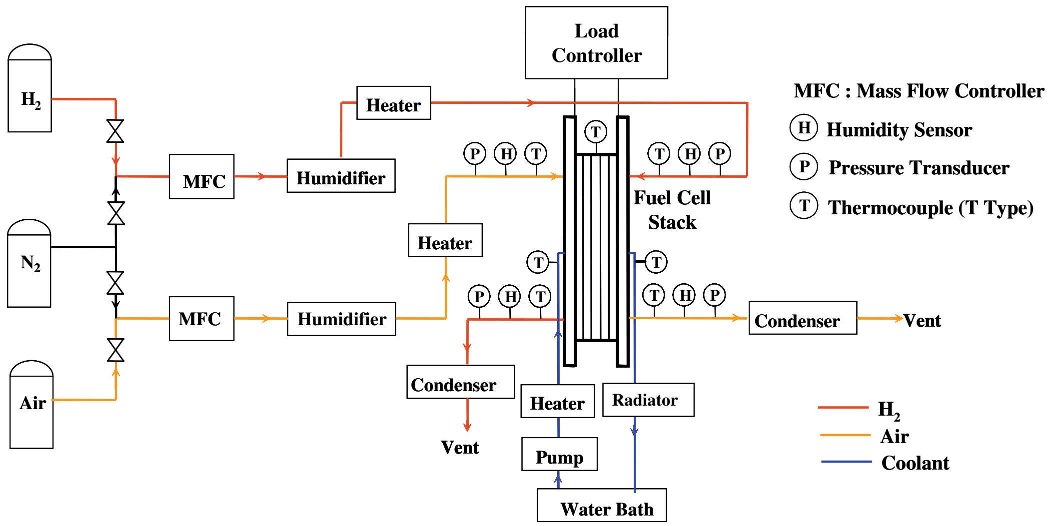

Fig. 1. Schematic diagram of test apparatus to evaluate a PEMFC performance.

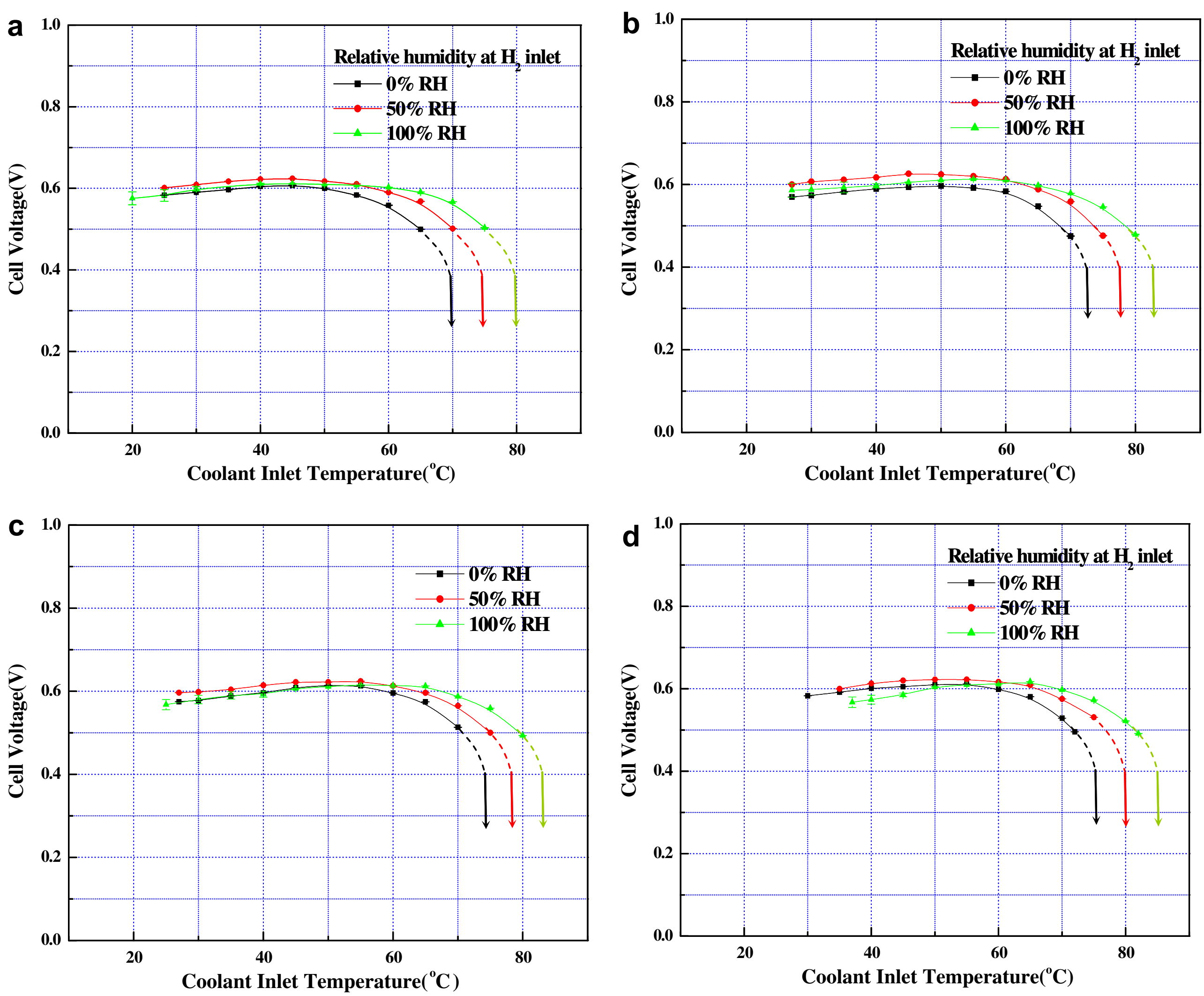

Fig. 2. Cell voltage according to coolant inlet temperature, coolant flow rate and relative humidity at H_2 inlet. (a) Coolant flow rate: 0.1 l/min cell; (b) coolant flow rate: 0.2 l/min cell; (c) coolant flow rate: 0.4 l/min cell; and (d) coolant flow rate: 0.8 l/min cell.