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Water recovery and air humidification by condensing the moisture in the outlet gas of a proton exchange membrane fuel cell stack

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ABSTRACT

Humidification is one of the most important factors for the operation of proton exchange membrane fuel cell (PEMFC). To maintain the membrane at hydrated state, plenty of water is needed for the state-of-the-art of PEMFC technology, especially in large power applications or long time operation. A condenser is introduced to separate liquid water from the air outlet for air self-sufficient in water of the stack in this study. The condensed temperature at the outlet of the condenser and water recovered amount for air self-sufficient in water are investigated theoretically and experimentally. It is shown that the condensed temperature for air self-sufficient in water is irrelevant with the working current of the stack. When the condenser outlet temperature was above the theoretical line, recovery water was not sufficient for the air humidification. On the contrary, it is sufficient while the temperature was below the theoretical line. It is also shown that when the moisture is sufficiently cooled, large amount water can be separated from the outlet gas, and it increased almost linearly with the time. With the introduction of the condenser, the recovered amount of water can easily satisfy the air self-sufficient in water by condensing the outlet gas to a proper temperature.

1. Introduction

Proton exchange membrane fuel cell (PEMFC) has been considered to be one of the promising power sources for portable devices, transportation and stationary applications due to its high energy conversion efficiency, high power density, quick startup, and low environment pollution [1–3]. Many aspects of PEMPEC, such as thermal management, temperature distribution, system optimization design et al., have been study for years [4–9]. However, one critical requirement for operated PEMFC is to maintain high water content in the electrolyte to ensure reasonable ionic conductivity. Therefore, water molecules must be supplied continuously to prevent drying of the membrane as can lead to dramatic decrease in ionic conductivity. To date, a variety of methods have been developed to make the membrane well humidified, and they are mainly categorized into external humidification and internal humidification, respectively.

External humidification refers to the process that membranes are humidified by humidified reactants gases through humidifiers prior to flowing into the cell and the humidification process mainly takes place outside of the fuel cell stack [10–16]. Since this process is relatively easy to be handled, it has been the most commonly used technique. Lee et al. [10] investigated the effects of external humidification to the membrane by varying the humidification side such as anode humidification, cathode humidification, and both anode and cathode humidification (called as both-side humidification). The results showed that the best performance of the cell was achieved by both-side humidification. The higher temperature in the anode humidification resulted in the degraded performance of the cell. Jung et al. [11] developed a scaled gas humidification system using injectors for PEM fuel cell vehicles. The humidification system consisted of an injector, a duplex enthalpy mixer and a water management apparatus. Humidification performance was observed to be critically affected by the temperature of injected water and the gas flow rate in their study, and inlet gas temperature also affected the humidification performance and response time. Sridhar et al. [12] investigated the external membrane humidification in the anode. The results showed that the water of solvation of protons decreases with increase in the current density and the electrode area, and the coolant water itself can be used for

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