A numerical analysis of mass transport in a fuel cell

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A numerical study on the water management in a polymer electrolyte membrane fuel cell (PEMFC) was performed. Both, a one-dimensional numerical analysis in the membrane-electrode assembly (MEA), and a three-dimensional numerical analysis in the cathode side of the flow channel were carried out to study water transport. In order to determine the operating condition with no dehydration of the water and/or flooding of the electrodes induced by an imbalance between production and removal rates of water, the effects of the operating pressure, and the thickness of membrane and the gas diffusion layer (GDL) on the cell performance were investigated by using numerical analysis of the MEA. Effects of the flow rate configuration and the flow channel arrangement on current density distribution were studied to optimize the fuel cell design with high-energy efficiency and high power density performance.

Fig.1 shows the water flow in the membrane. The flow rate of water in the membrane becomes zero when the current density is about 0.4 A/cm^2, because at this point the electrokinetic flow of water becomes equal to the pressure driven flow of water. Fig.2 presents the effect of anode channel pressure on water transport in the membrane. When the pressure of cathode channel is higher than one of anode channel, dehydration of the water in the membrane can be controlled.

The effects of structure and flow velocity on the cell performance are studied at a constant cell temperature in the fuel cell. Computations were carried out for two different inlet flow rates, namely, 1.37×10^{-5} [m^3/s] (Q_1) and 1.37×10^{-6} [m^3/s] (Q_2). Fig.3 shows the schematics of the three-dimensional analysis. Table 1 presents the details of flow channel dimensions. The effect of flow structure on current density at inlet flow rate (Q_1) is given in Fig.4. Fig.5 shows the variation of the current density. From these figures, one can be see that the current density value depends on the inlet flow rate and flow structure. Especially, it is shown that insufficient gas flow rate induces seriously low performance of fuel cell in the serpentine flow structure. Even though the cell size is small, the dependency of cell structure on cell performance is significant.

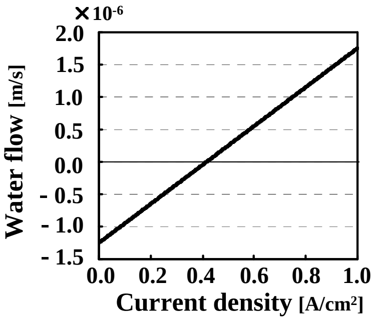
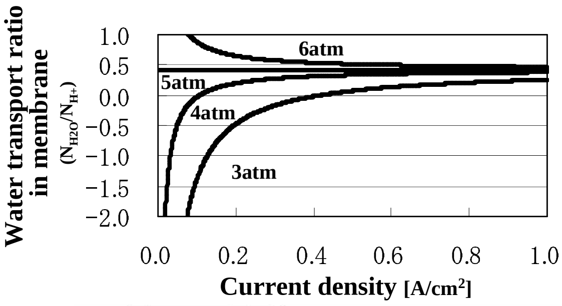


Fig.1 Effect of current density on water flow in the membrane.



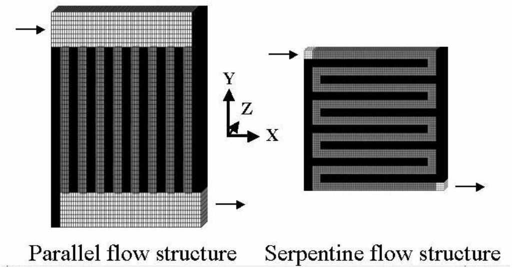


Fig.3 Schematics of the three-dimensional analysis.

	Parallel	Serpentine
Cell size (x×y×z) [mm^3]	17.0×24.0×1.0	18.1×18.1×1.0
Reaction area [mm^2]	144	144
Cross section area of each channel (x×z) [mm^2]	1.0×1.0	1.06×1.0
Cross section area of inlet (y×z)[mm^2]	3.0×1.0	1.06×1.0

Table 1 Details of sizes of flow channels.

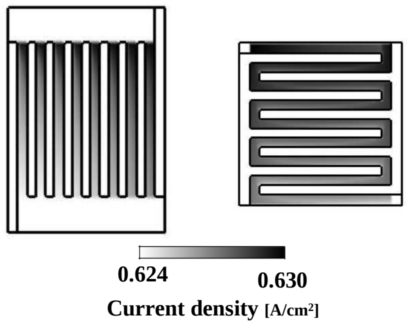


Fig.4 The effect of structure of flow channel on current density under condition Q_1.

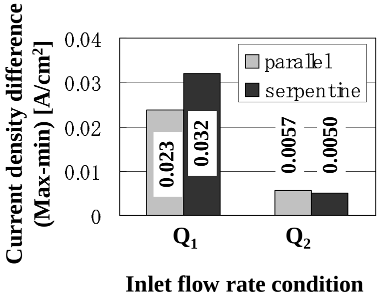


Fig.5 The effect of flow rate on current density difference between maximum and minimum values.