

**Experimental study with different cathode and anode humidification temperatures in PEM fuel cell**

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**ABSTRACT:** The paper gives experimental study and analysis of PEM Fuel cell with different humidification temperature. The paper focuses on the effect on the voltage and power obtained from fuel cell under variable humidification temperatures. An experimental setup of PEM fuel cell has been developed for this study.

The effects of different operating parameters on the performance of proton exchange membrane (PEM) fuel cell have been studied experimentally using pure hydrogen on the anode side and air on the cathode side. Experimental analysis has been done with different cathode and anode humidification temperatures. The experimental results are presented in the form of polarization curves, which show the effects of the various operating parameters on the performance of the PEM fuel cell. The possible mechanisms of the parameter effects and their interrelationships are discussed.

**KEYWORDS:** PEM fuel cell, Anode material, Cathode Material, Pressure Range, humidification Temperature Range.

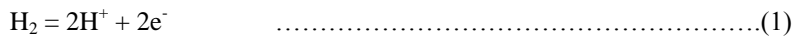
**I. INTRODUCTION**

Proton exchange membrane (PEM) fuel cells have been widely recognized as the most promising candidates for future power generating devices in the automotive, distributed power generation and portable electronic applications. The proton exchange membrane fuel cell (PEMFC) is of great interest in energy research field because of its potential application for conversion of chemical energy into electrical energy with high efficiency, high power density, low pollution and low operating temperature.

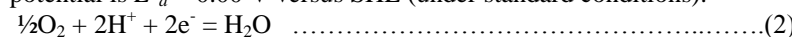
**II. Principle of PEM Fuel Cell**

The working of PEM Fuel cell is shown in the Figure 2.1. Hydrogen is fed to the anode side, while oxygen is fed to the cathode side. The fuel, in this case hydrogen, is oxidized at the anode to produce positively charged protons and negatively charged electrons. The protons can pass through the hydrated PEM to the cathode as hydronium ions, while the electrons travel along an external circuit, also to the cathode. In this way, electro-neutrality (charge balance) is maintained. The protons and oxygen molecules are combined with the electrons at the cathode. Oxygen is reduced by the electrons and combined with the protons to produce pure water and heat. Again, the process can be simplified into separation (anode) and recombination (cathode) of charges, and the associated increase (energy source) or decrease (energy sink) in the system's electrical energy.

**Fuel cell electrochemical reactions (Thermodynamics):** A hydrogen PEM fuel cell operates on two coupled half reactions, that of the hydrogen oxidation reaction (HOR) at the anode, and the oxygen reduction reaction at the cathode (ORR). Other fuels can be oxidized at a PEM fuel cell anode, such as methanol, ethanol, and formic acid. The anode and cathode electrochemical reactions are shown below.

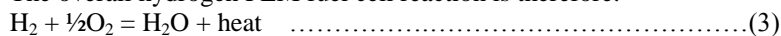


Where the corresponding anode thermodynamic potential is  $E^o_a = 0.00$  V versus SHE (under standard conditions).



Again, the corresponding cathode potential is  $E^o_c = 1.229$  V versus SHE (under standard conditions).

The overall hydrogen PEM fuel cell reaction is therefore:



With the standard equilibrium electromotive force calculated to be 1.229 V.

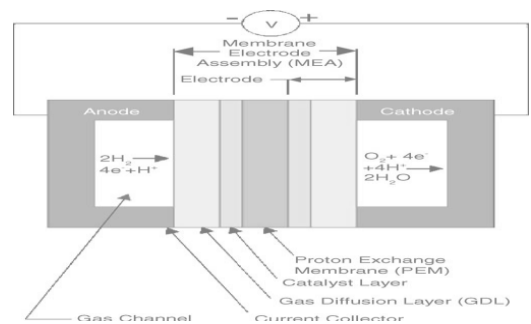


Figure 2.1: Schematic Diagram of PEM Fuel Cell

**III (A). Experimental Setup**

Experimental setup are the combination of two major plates such as , anode plates and cathode plates, which has been well design and construction with as per specification. A single unit cell with active surface aria of 7.2 x 7.2 c.m. was used for experiment in this study. The membrane electrode assembly (MEA) consists of a Nafion in combination with platinum loadings of 0.4 mg/cm<sup>2</sup> per electrode. The gas diffusion layers are made of carbon fiber cloth. The MEA positioned between two graphite plates is pressed between two gold-plated copper plates. The graphite plates are grooved with serpentine gas channels. In the test station, reactant gases are humidified by passing through external water tanks. Regulating the water temperature controls the humidification of the reactant gases.

### III (B). Experimental procedure

The procedure for each experiment is as follows:

1. Power on the Fuel Cell Test Station and open the valves of the gas cylinders of hydrogen, oxygen.
2. Before starting experiments, purge the anode side with hydrogen to ensure no oxygen is present.
3. Set the experimental parameters of mass flow rate of the gas cylinders of hydrogen, oxygen.
4. Set the maximum voltage, minimum voltage and voltage increment step of the fuel cell polarization data by Ammeter and Voltmeter.
5. Set the delay between every two voltage and current data points.



Figure 3.1: Ammeter and Voltmeter



Figure 3.2: Hose Pipe Zone



Figure 3.3: Pressure Gauge



Figure 3.4: Flow Meter Arrangement



Figure 3.5: Experimental setup of PEM Fuel cell

### IV. Result and discussion

#### 4.1 Effect of the humidification in plates

When the anode humidification temperature is at 40°C, the current density of the fuel cell is the lowest at a given voltage. graph shows that the linear portion of the polarization curve for different anode humidification temperatures are almost parallel to each other, which indicates that the electrical resistance of the fuel cell causing the ohmic losses does not vary significantly.

At low current densities, lower the anode humidification temperature, the lower the cell voltage. This phenomenon could be explained by the decrease of the active catalyst surface area caused by lack of water in the catalyst layers. When the anode is dry, the water transfer through the membrane from the cathode side to the anode side due to back-diffusion is dominant.

This is even more pronounced at low current densities, when water transfer due to electro-osmosis is low. The result of the combined effect is water deficiency in the cathode catalyst layer. At higher current densities, the cell voltages at different anode humidification temperatures come closer. This, again, could be explained by hydration of the catalyst layer. At high current densities, water generation rate is high and water transfer due to electro-osmosis is high. Thus the cathode catalyst layer is better hydrated even though the anode humidification is low.

**Table 1:** Data for different humidification temperatures, backpressures are 4 atm on both the anode and cathode sides and hydrogen flow rates are 1.0 ml/s and Oxygen flow rates 2.0 ml/s.

Sr. No.	Current density (A/cm <sup>2</sup> )	Voltage at humidification temperature 40°C	Voltage at humidification temperature 60°C	Voltage at humidification temperature 80°C
1	0.2	0.91	0.92	0.93
2	0.4	0.78	0.80	0.83
3	0.6	0.74	0.75	0.77
4	0.8	0.71	0.72	0.73
5	1.0	0.69	0.70	0.71
6	1.2	0.61	0.64	0.68

**Table 2:** Data for different humidification temperatures, backpressures are 4 atm on both the anode and cathode sides and hydrogen flow rates are 2.0 ml/s and Oxygen flow rates 4.0 ml/s.

Sr. No.	Current density (A/cm <sup>2</sup> )	Voltage at humidification temperature 40°C	Voltage at humidification temperature 60°C	Voltage at humidification temperature 80°C
1	0.2	1.02	1.04	1.05
2	0.4	0.96	0.97	0.98
3	0.6	0.94	0.95	0.96
4	0.8	0.92	0.93	0.94
5	1.0	0.90	0.91	0.92
6	1.2	0.78	0.801	0.821

**Table 3:** Data for different humidification temperatures, backpressures are 4 atm on both the anode and cathode sides and hydrogen flow rates are 3.0 ml/s and Oxygen flow rates 6.0 ml/s

Sr. No.	Current density (A/cm <sup>2</sup> )	Voltage at humidification temperature 40°C	Voltage at humidification temperature 60°C	Voltage at humidification temperature 80°C
1	0.2	1.09	1.11	1.12
2	0.4	0.99	1.08	1.09
3	0.6	1.02	1.04	1.05
4	0.8	0.96	0.97	0.98
5	1.0	0.94	0.95	0.96
6	1.2	0.92	0.93	0.94

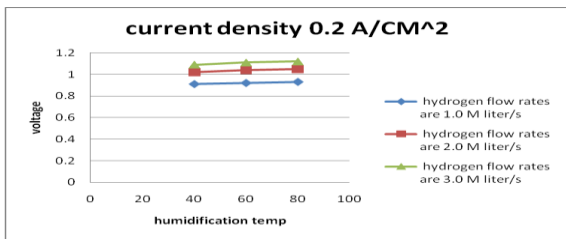


Fig. 4.1. Different mass flow rates curves for cell humidification temperature vs. cell voltage at 0.2 current density

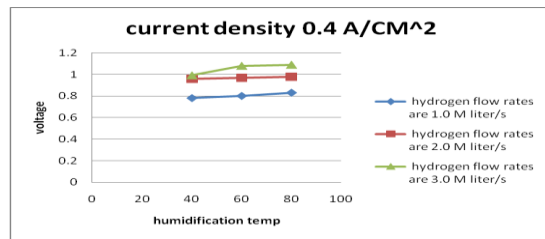


Fig. 4.2. Different mass flow rates curves for cell humidification temperature vs. cell voltage at 0.4 A/cm<sup>2</sup> current density

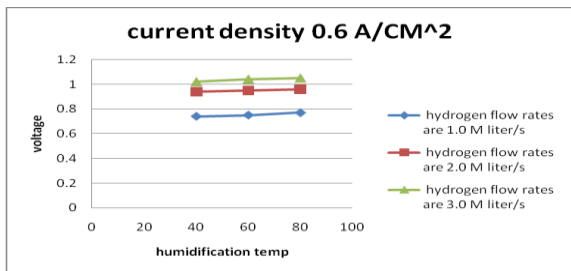


Fig. 4.1. Different mass flow rates curves for cell humidification temperature vs. cell voltage at 0.6 A/cm<sup>2</sup> current density

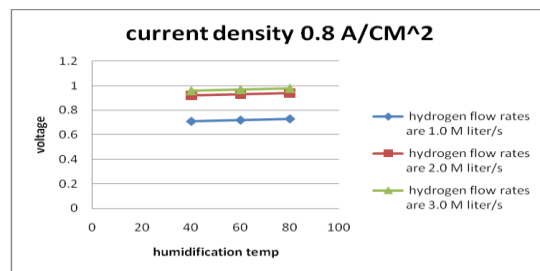


Fig. 4.2. Different mass flow rates curves for cell humidification temperature vs. cell voltage at 0.8 A/cm<sup>2</sup> current density

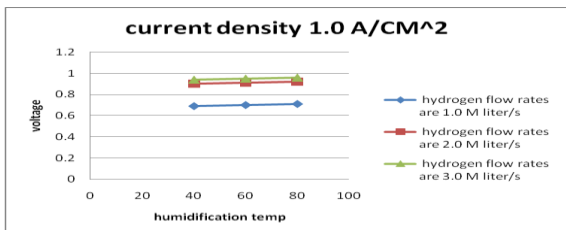


Fig. 4.1. Different mass flow rates curves for cell humidification temperature vs. cell voltage at 1.0A/cm<sup>2</sup> current density

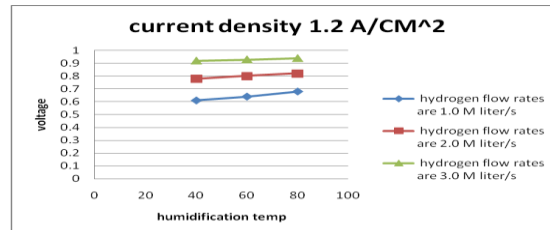


Fig. 4.2. Different mass flow rates curves for cell humidification temperature vs. cell voltage at 1.2 A/cm<sup>2</sup> current density

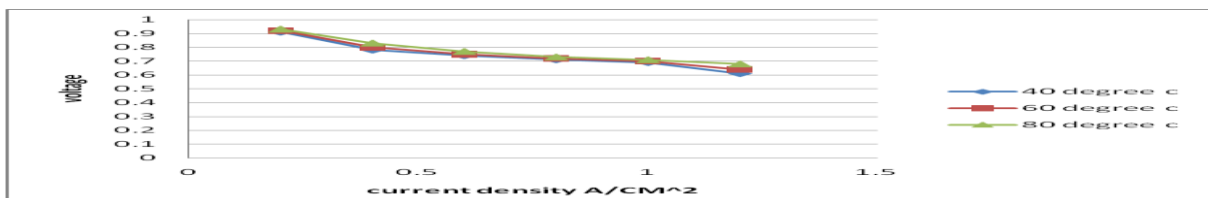


Figure 4.6: Humidification temperatures with hydrogen flow rates are 1.0 ml/s and Oxygen flow rates 2.0 ml/s.

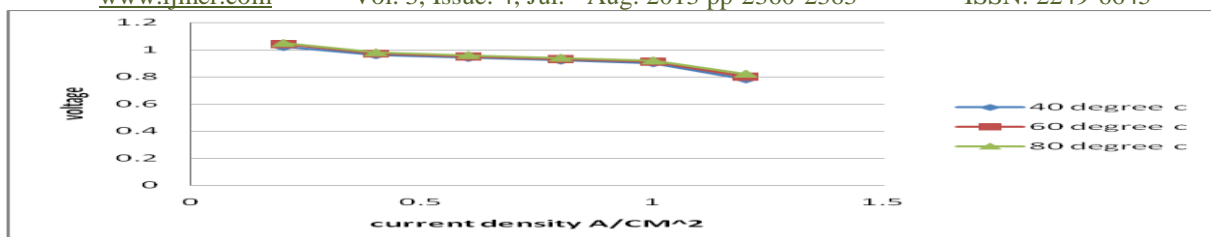


Figure 4.7: Humidification temperatures with hydrogen flow rates are 2.0 ml/s and Oxygen flow rates 4.0 ml/s.

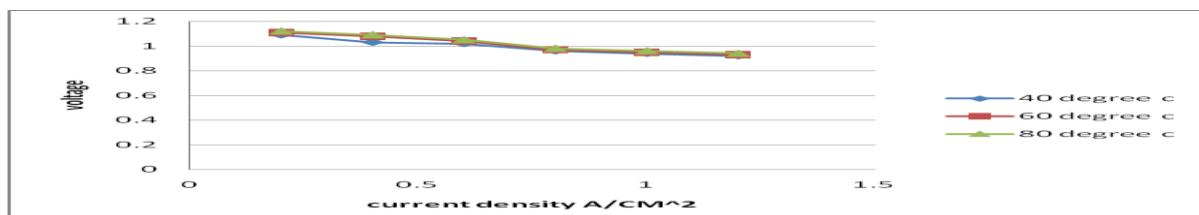


Figure 4.8: Humidification temperatures with hydrogen flow rates are 3.0 ml/s and Oxygen flow rates 6.0 ml/s.

## V. CALCULATIONS

Table 5.1 presents the Improvement in Voltage of variable Mass Flow Rate and Current Density of Fuel Cell

Table 5.1: Improvement in Voltage of variable Mass Flow Rate and Current Density of Fuel Cell

Current density (A/cm <sup>2</sup> )	Humidification Temperature (°C)	hydrogen flow rates (case I) (ml/s)	Oxygen flow rates (case I) (ml/s)	Voltage (case I) (V)	hydrogen flow rates (case II) (ml/s)	Oxygen flow rates (case II) (ml/s)	Voltage (case II) (V)	Increase in voltage (%)
0.2	80	1.0	2.0	0.93	3.0	6.0	1.12	20.43%
0.4	80	1.0	2.0	0.83	3.0	6.0	1.09	31.32%
0.6	80	1.0	2.0	0.77	3.0	6.0	1.05	36.36%
0.8	80	1.0	2.0	0.73	3.0	6.0	0.98	34.24%
1.0	80	1.0	2.0	0.71	3.0	6.0	0.96	35.21%
1.2	80	1.0	2.0	0.68	3.0	6.0	0.94	38.23%

## VI. CONCLUSION

In this work, humidification temperatures and pressures have been performed. Voltage is increase 38.23% by increasing the different humidification temperatures and mass flow rates. When enough humidification is provided, the performance of the PEM fuel cell improves with the increase of operation temperature.

1. During the process we found that Voltage is increased 38.23%, when the fuel cell is 80<sup>0</sup>C and at fixed Current density of 1.2 A/cm<sup>2</sup>.
2. During the process we found that Voltage is increased 35.21%, when the fuel cell is 80<sup>0</sup>C and at fixed Current density of 1.0 A/cm<sup>2</sup>.
3. During the process we found that Voltage is increased 34.24%, when the fuel cell is 80<sup>0</sup>C and at fixed Current density of 0.8 A/cm<sup>2</sup>.
4. During the process we found that Voltage is increased 32.36%, when the fuel cell is 80<sup>0</sup>C and at fixed Current density of 0.6 A/cm<sup>2</sup>.
5. During the process we found that Voltage is increased 31.32%, when the fuel cell is 80<sup>0</sup>C and at fixed Current density of 0.4 A/cm<sup>2</sup>.

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