Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 52(6) (2020) 371-374
DOI: 10.22060/mej.2018.14354.5842

Study of Temperature Distribution of H2/O2 Polymer Electrolyte Fuel Cell in Different Operating Conditions

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ABSTRACT: The fuel cell is an electrochemical energy exchanger that directly converts the chemical energy into direct current and heat. Thermal management and water management are two major challenges in designing and efficiency of polymer fuel cells, which are inherent in each other. In this paper, by manufacture polymer electrolyte membrane fuel cell and test under different conditions, an analysis will be made of how the temperature is distributed in the full cell. By studding this temperature distribution, the relationship between power generation and heat distribution, thermal parameters (temperature distribution, maximum and minimum temperature) are extracted. The innovation aspect of this paper is to achieve an understanding of the distribution of temperature in polymeric fuel cell under different operating conditions. Also, the temperature distribution has been investigated in open-end and dead-end operating modes in different pressures and stoichiometries. When the fuel cell is changed from the open-end to the dead end mode, the maximum temperature changed from the outlet section in to the input section. By increasing pressure, the importance of maldistribution control and design of a suitable cooling system will increase.

Review History:

Received: 24 Apr. 2018
Revised: 14 Sep. 2018
Accepted: 3 Dec. 2018
Available Online: 11 Dec. 2018

Keywords:

Thermal imaging
Polymer electrolyte membrane fuel cell
Temperature distribution
Operating conditions
Dead end mode.

1- Introduction

The world needs a source of energy that has low emissions, high-energy efficiency, and unlimited reserves for the growing population of the world. Fuel cells are known as one of the most promising technologies for achieving these goals [1]. The fuel cell is an electrochemical energy converter that directly converts the chemical energy of the fuel into an electric current.

Similar fuel cell electric power output, also produces waste heat as the energy efficiency of around 50% [2]. That is, for a 100 kW powered fuel cell engine, the heat dissipation rate would be 100 kW. As a result, this heat dissipation in the fuel cell has a direct relationship with the power output of the fuel cell. The correct inference from the heat generated in the fuel cell and its effects is very important in optimizing the efficiency and lifetime of the proton exchange membrane fuel cell.

Research has tried to find out how heat is distributed and analyzed in a fuel cell, such devices used as thermal cameras, infrared thermometers, thermo sensitive thermochromic liquid crystals, and small scale sensors.

Wang et al. [3] in 2006 to investigate the temperature distribution on the surface with their simple serpentine flow field. With the help of the thermal camera (Fig. 1) showed the distribution of the anode side temperature, with the input of dry gas, in the current density, experimental results showed that the downstream of the channel are warmer than the upstream points of the channel. Fabian et al. [4] used a micro sensor to measure temperature distribution in 2007. Measurement of the partial pressure of oxygen and relative humidity in the mass transfer layer was carried out .This showed that the major changes in the concentration of reactive species and the distribution of temperature were caused by increasing the current density.

In previous studies on the distribution of temperature in fuel cell, considering the advantages and disadvantages of measuring instruments, the use of thermal camera for this research was selected. Due to the lack of physical contact, the electrical noise of the fuel cell (for example, the negative effect on the thermocouple) does not affect it. For operational conditions, most studies have only dead-end the anode side and the cathode side has not been considered. Showing this analysis is one of the highlights of this article.

Fig. 1. NEC 5102TH thermal camera image used by Wang et al. [3]

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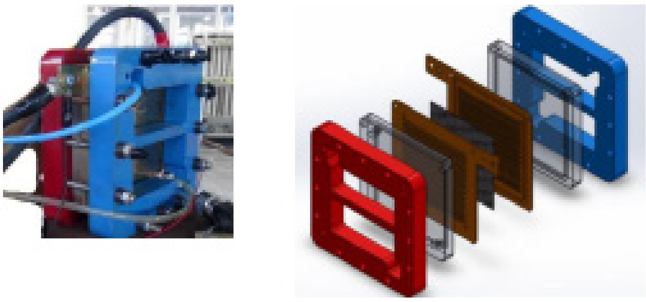

Fig. 2. Overview of single-cell fuel cell designed, a) Total single-cell designed (right), b) Sample built (left)

Fig. 3. Fuel cell testing system along with the thermal camera

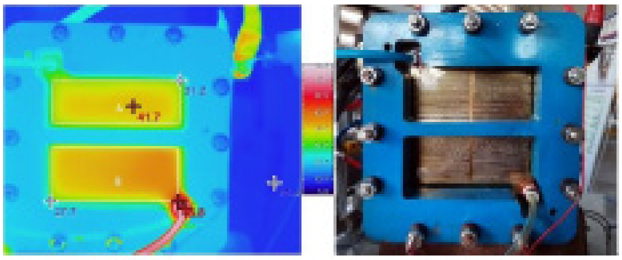

Fig. 4. Temperature distribution of single-cell in the end of activation the at current density of 0.54 A/cm2

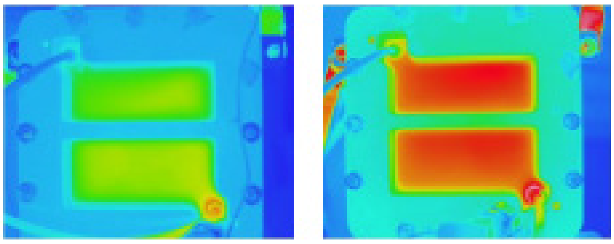

Fig. 5. Thermal imaging of the cathode surface at a current density of 0.25 A/cm2 and P=1 barg in a) open end mode and Stoichiometry of hydrogen and oxygen equal to St=4 (left) and b) dead end mode (right)

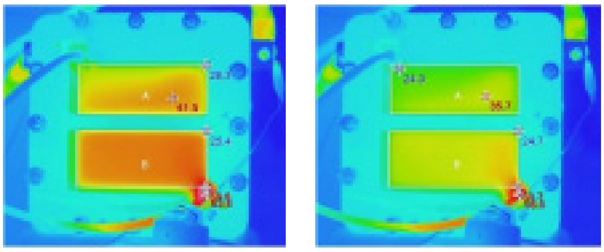

Fig. 6. Thermal imaging of the cathode surface of the open end mode at StH2=StO2=2, I=84.4 A, operating pressure: a) P=1 barg (left) and b) P=0.5 barg (right)

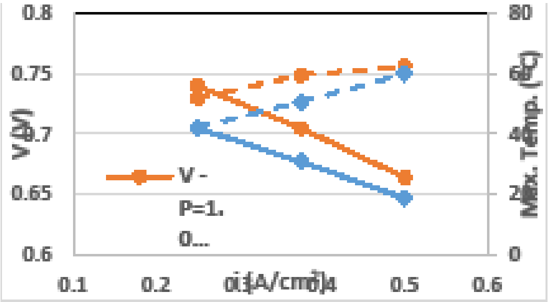

Fig. 7. Diagram of voltage and maximum surface temperature in terms of variation of current density

2- Experimental Test Setup

To thermal analysis of the Polymer Electrolyte Membrane (PEM) fuel cell, it is necessary to construct a single cell with transparent end plates (Fig. 2), so that the infrared camera can directly measuring temperature from the channel surface and the gas diffusion layer. For this test, the transparent PEM fuel cell made by Rahimi et al. [5] was used.

The heat analysis test setup was fitted using a NEC thermal camera (Fig. 3). Test inputs parameters such as pressure, stoichiometry, temperature, humidity are controlled by a control software. Determining the temperature range, focusing on the thermal camera, averaging and dividing the image into different sections, and displaying the maximum and minimum temperatures through the thermal camera software.

3- Results and Discussion

In this section we present the results of temperature distribution in different operating conditions. First, the transparent PEM is displayed at the end of the activation process. Gas stoichiometry in this case is equal to 2 and the current is 122A at a voltage of 0.6V. Regarding the pressure and stoichiometry of the reactants, the reaction takes place on the whole surface and the gases pass through the flow field and the temperature goes up to 70 °C (Fig. 4).

In Fig. 6, two temperature contours are compared in two dead-ends and an open-end mode in the same current density.

The average dead-end temperature is in the range of 51°C and the open-end mode is 35°C. The cathode surface in the dead-end mode due to convection heat transfer by means of a high gas reactor with stoichiometry 4 has a uniform temperature distribution.

In Fig. 6, the temperature distribution of two operating pressure of 0.5 and 1.0 barg in the current of 84.4 A was shown. Due to the increase of surface temperature with increasing pressure, the efficiency improvement is observed and average cell voltage increased by 4% as shown in Fig. 7.

4- Conclusions

With PEM fuel cell designed and thermal camera technology, the temperature distribution of fuel cell cathode surface in a dead-end and open-end mode was experimentally investigated under various operating conditions. The following results can be extracted from this article:

1) In the open-end mode, the downstream temperature was higher than to the upstream, because the hydrated membrane was more complete along the path and the reaction was better formed in the downstream.

2) As the load increases, the reaction rate increases and the average temperature of membrane surface and cell increases. 3) In the dead-end mode, the temperature of downstream flow decreased, due to visual observations, water flooding accrued and the decrease in the rate of diffusion of reactive gases into the membrane, thereby reducing the reaction rate and resulting lower temperature at the output. 4) Increasing the stoichiometry resulted in an increase in the convective heat transfer rate and a decrease in the average surface temperature, and temperature maldistribution decreased in constant current density.

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