Energy 143 (2018) 284–294

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Energy and exergy analyze of PEM fuel cell: A case study of modeling and simulations

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ARTICLE INFO

Article history:
Received 9 July 2017
Received in revised form
3 October 2017
Accepted 22 October 2017

Keywords:
PEM fuel cell
Energy and exergy efficiency
Uncertainty analysis

ABSTRACT

This study presents the performance of a proton exchange membrane (PEM) fuel cell in terms of its pressure and voltage parameters. The aim of this study is to improve the performance, efficiency and development of modeling and simulations of PEM fuel cells by experimental optimization. PEM fuel cell performance was researched using an open cathodic plate fuel cell, the effect of fuel cell's performance. PEM fuel cell efficiency was measured in terms of operating pressure and voltage parameters. The energy and exergy efficiencies of the PEM fuel cell were found to be 47.6% and 50.4%, herein. In this study, these results indicate that waste water of experimental work comprehends importance of the PEM fuel cell life-time.

1. Introduction

Nowadays, the alternative energy options begin to gain important state because of the depletion of fossil fuels. These options require significant experimental and prototype work to realize new energy sources. In this study, a small scale modeling and simulation of the proton exchange membrane (PEM) fuel cell was considered to find new alternative solutions. The purpose of this work was to investigate a platinum catalyzed PEM fuel cell for the development of small scale modeling and simulations. Fuel cell voltage and current parameters are experimentally observed depending on the functions of time. This fuel cell with a cathodic plate, which was designed as a part of the cell's membrane electrode assembly (MEA), can take O_2 gas directly from the air by natural convection. The performance of a PEM fuel cell is determined by its cathodic plate. Through these study measurements, the effects of hydrogen feeding and performance-based optimizations were determined by experiments on a single fuel cell. The observed voltage and current parameters were characterized in this experimental study. This study researched to find the best solution for wastewater management in micro-scale PEM fuel cells, as well as to improve cell performance and efficiency.

Hydrogen was described in many previous studies. In a remarkable study, hydrogen is defined in a very comprehensive manner. Hydrogen was defined by Ozlu and Dincer [1]. In this definition, hydrogen gas is used to store energy in order to balance the incompatibility between demand and supply while dealing with renewable resources [1]. Hydrogen gas is not only the main energy source but also a gas element with high electrical energy conductivity. In this study, some technical features of hydrogen gas can be given because of using hydrogen gas. Hydrogen gas can be converted to a liquid equivalent to 1 [kg] of hydrogen, 2.1 [kg] of natural gas and 2.8 [kg] of petroleum at a temperature of −252.77 [°C], while the amount of low heat value for the H_2 gas is about 120.7 [MJ/kg]. The density of hydrogen gas (1 atm pressure at sea level) is known as 1.43 [g/m^3].

Today, several in-plant aircraft, automobiles, spacecraft and similar vehicles use efficient PEM fuel cells. After thoroughly reviewing the literature, it was determined that the most important problem affecting the fuel cells is the durability. Similar previous studies are available in the literature. These manufacturing production were probably to be considerable alternative energy sources for hydrogen fuel power, recycling energy systems, portable electronic devices whose durability was embraced by Huang and Reifsnider [2] and Emery et al. [3]. Mirzaei et al. [4] investigated on durability and performance study of hydrothermal synthesized platinum-multi walled carbon nanotube nanocomposite catalyst for PEM fuel cell. Accelerated durability testing was applied for MEAs in a high-potential operation on a fuel cell test station by Mirzae et al. [4]. In the PEM fuel cell, the mass and water transport of water management was found to be important [5]. In the experimental study of PEM fuel cell it was stated that water management should be

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https://doi.org/10.1016/j.energy.2017.10.102
0360-5442/

regulated to be effective. It was also determined that cell performance would increase with better management of waste water [5]. In both experimental and theoretical research, it was found that a PEM fuel cell may affect the performance of water input and output [6]. In another study, Zhang et al. [7] observed the performance of PEM fuel cells and found that when the flow rate is low, cell load and performance can increase, except for the case of gas diffusion plates. Kong et al. [8] noted that it is important to quickly remove water from the PEM fuel cell gas diffusion layer. Dokkar et al. [9] showed that fuel cell membrane content and properties are based on parameter effects and ionic conductivity studies. Bao et al. [10] proposed that humidity is a very important parameter from the viewpoint of fuel cell performance. When hydrogen and oxygen gases entered a fuel cell, humidity within the cell leaded to better cell performance.

The anode feeding is used as a hydrogen gas source as it provides proton ion flow. H_2 gas enters the PEM fuel cell anode section via catalyst to form the proton ion. In order to generate electricity by electron movements, the hydrogen gas passes through the proton membrane and the electrons passing through the cathode part undergo chemical interaction with the oxygen electrons. In another study, Ekiz et al. [11] showed that by increasing the inlet velocity and the exit pressure based on the boundary operating conditions at the cathode, increasing oxygen supply to the anode could improve cell performance.

In this study, the stoichiometric air ratio and performance effects of air polluted natural fuel cells were examined based on the previous study [3]. In another work in the literature, the wastewater balance of a fuel cell in the cathode section was elaborated. High resolution neutron radiography was used in the anode plate. Saturation profiles were found to change in the diffusion medium. The gradients of pressure and relative humidity in a fuel cell membrane electrode setup were discussed by La Manna et al. [12]. In the present work, the advantages and disadvantages of the fuel cell must first be known in order to be able to grasp well. Andujar and Segura [13], Chandan et al. [14], Asensio et al. [15], Devanathan [16], Rikukawa and Sanui [17], Neelakandan et al. [18], Li et al. [19] and Taner [20] indicated that PEM fuel cells have significant advantages in terms of electrode kinetics, heat and water management, alternative catalysis, high power density and low operating temperature. Besides, Liu et al. [21] noted that the PEM fuel cell has received great interest in recent years due to its advantages such as high efficiency and low emission. However, Andujar and Segura [13], Chandan et al. [14], Larminie and Dicks [22], Li et al. [23], Villers et al. [24] and Oh et al. [25] posed that high sensitivity was a disadvantage in the case of membranes and materials, fuel cell membrane durability, gas diffusion layer degradation and gasification difficulties during manufacturing. Mekhilefa et al. [26] showed that PEM fuel cells could have an efficiency of up to 40%. Researchers determined that it was possible to control the heat and water in a PEM fuel cell to obtain high performance. Protons H^+ was found to lead to considerably greater amount of water vaporisation than the amount of water that could enhance the efficiency of a fuel cell when an anatomic catheter was transmitted correctly. In addition, Taner [20] and Kim et al. [27] showed that the durability of PEM fuel cells decreases at high temperatures. Although one of the most critical features of PEM fuel cell is durability, it can be solved by the management of water waste. Taner [20] and Kim et al. [27] predicted that the PEM would make a large contribution to fuel cells. Taner [20] and Attaran et al. [28] also assumed that the performance and efficiency rates of PEM fuel cells could be effective under low humidity conditions. The chemical reaction of platinum and catalyst was demonstrated by Taner [20] and Choi et al. [29] through the fuel cycle. Taner [20] and Tiwari et al. [30] observed that the fuel cell performance might degrade if the platinum value could be high. Conversely, the reason for the high efficiency of PEM fuel cells was zero emission, as it was addressed by Taner [20] and Higgins et al. [31]. The parameters that could be observed in a PEM fuel cell experimental study were temperature, current and voltage. The effects of these parameters on the performance of PEM fuel cells were demonstrated by Amirinejad et al. [32] and Hakenjos [33]. In addition, the neutralised water transport method and flow in the PEM fuel cell cycle have been shown by Arif et al. [34]. Perna et al. [35] researched on an advanced power system based on a high temperature polymer electrolyte membrane fuel cell and an organic Rankine cycle for heating and power production. Apart from these studies, micro and macro-scale transport processes to improve PEM fuel cell performance were proposed by Owejan et al. [36]. In literature, there was a new study about an artificial neural network (ANN) approach of a smart grid integrated PEM fuel cell, which was determined by Bicer et al. [37].

A flow and voltage statistical correlation analysis method for characterising the PEM fuel cell process flow was shown by Giurgea et al. [38]. An examination of similar studies in the literature revealed that they were often found to work like fuel cell durability, water management and material properties. This study was based on the PEM fuel cell's performance analysis of similar theoretical and experimental studies in the literature.

According to the literature, parametric (operating current density, temperature and pressure of the PEM fuel cell) analysis of an irreversible PEM fuel cell was designed by Yang and Zhang [39].

This study presented the performance of PEM fuel cells in terms of pressure and voltage parameters. This study also aimed to improve the performance, efficiency and development of modeling and simulations of PEM fuel cells with various optimizations. PEM fuel cell performance was explored by the effect of a cathodic plate fuel cell and fuel cell performance. PEM fuel cell efficiency was determined by operating pressure and voltage parameters.

2. Material and method

In Fig. 1, a working principle diagram of the PEM fuel cell, a general view of the PEM fuel cell during the experiment and a software screen are shown. During the PEM fuel cell experimental run the distance between the cells was adjusted with a 1.4 Nm torque meter. The system was activated with hydrogen gas. The required pressure adjustments were made. Pragma Industries [40] software has been used for the view of parameters. With different optimizations, the voltage and pressure values were adjusted for performance improvements. The voltage, current and temperature parameters were controlled by adjusting software with computer. The voltage and current were controlled and monitored with software monitor. In software monitor, Voltage Set - Current Set adjusted voltage, current and temperature. In addition, Data Logger Setup regulated and controlled the sample rate and time in the software monitor. Short Circuit Unit also regulated from software by frequency. The pressure parameters were controlled by adjusting pressure regulator with manual hand. These modified parameters are as follows; 1–5 V voltage with 1 bar pressure, 1–5 V voltage with 1.5 bar pressure, 1–5 V voltage with 2 bar pressure. Findings related to these values were discussed. For 15 min, deny results were obtained in 9 different parameters. Hydrogen entered the PEM fuel cell anode section through the catalyst to form the electron proton ion. Hydrogen gas passed through the proton membrane to generate electricity by the movement of electrons. Electrons passing through the cathode side underwent chemical interactions with the electrons of oxygen. Water formed proton ion. Chemical