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Performance Analysis of Temperature Changes of Fuels Used in Pem Fuel Cell

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ABSTRACT

In this study, the temperature values of the fuels used in Polymer Electrolyte Membrane (PEM) fuel cell were determined and the optimum temperature ranges were obtained for these fuels. Pure hydrogen and oxygen were used in the anode and cathode portions. In this study, moisture was taken as 40%, hydrogen amount as 0.3 ml/min and oxygen amount as 0.5 ml/min. Line temperature values in the system were also tested between 40-80°C with a 5°C difference. In the experiments carried out at 40°C, when the voltage value was taken as 0.442V and the current value was taken as 1.81A, the power value obtained in the system was found to be 0.804W. In the experiment, when the current value is 1.8A and the voltage value is 0.535V at 75°C, the power value in the system is found to be 1.025W. The lowest W value was calculated as 0.804W at 40°C and the highest W value was calculated as 1.025W at 75°C.

Pem Yakıt Hücresinde Kullanılan Yakıtların Sıcaklık Değişimlerinin Performans Analizi

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Özet

Bu çalışmada Polimer Elektrolit Membran (PEM) yakıt hücresinde kullanılan yakıtların sıcaklık değerleri belirlenmiş ve bu yakıtlar için optimum sıcaklık aralıkları elde edilmiştir. Anot ve katot kısımlarında saf hidrojen ve oksijen kullanıldı. Bu çalışmada nem oranı %40, hidrojen miktarı 0,3ml/dak ve oksijen miktarı 0,5ml/dak olarak alınmıştır. Sistemdeki hat sıcaklık değerleri de 40-80°C arasında 5°C farkla test edildi. 40°C'de yapılan deneylerde gerilim değeri 0,442V ve akım değeri 1,81A olarak alındığında sistemde elde edilen güç değeri 0,804W olarak bulunmuştur. Deneyde akım değeri 1,8A ve gerilim değeri 0,535V olduğunda 75°C'de sistemdeki güç değeri 1,025W olarak bulunmuştur. En düşük güç değeri 40°C'de 0,804W, en yüksek güç değeri 75°C'de 1,025W larak hesaplanmıştır.

1. INTRODUCTION

One of the areas where hydrogen energy is used economically and efficiently is fuel cells. Fuel cells are generally known as devices that convert the chemical energy of the fuel directly into electrical energy through electrochemical reactions. The products produced by the conversion of fuel cells using hydrogen gas are only heat and water. PEM fuel cells in fuel cells have remarkable advantages in many areas such as transportation, portable power and local power generation. Compared to other designs, PEM fuel cells operate at lower temperatures, occupy less volume, are lightweight and easy to operate. Literature studies have been carried out on fuel cell performance applications, which have an important place in alternative energy sources, which have received great attention in recent years and whose research and development activities continue. In the study of experiments, it was found that the temperature ratio of fuel cells was changed and experiments were conducted. As a result of the experiments and calculations, the operating temperature of the fuel at the optimum performance was determined in the fuel cells.

Strahl and Ramon Strahl examined the effects of temperature parameter on PEM fuel cell performance [1]. Lee et al. aimed to design cathode flow areas to reduce passive air-cooled PEM fuel cell dehydration and unbalanced performance problems [2]. Chug et al. evaluated the performance of hydrogen and battery used in a PEM fuel cell and examined the effects of different pollutants [3].

Søndergaard et al. stated that an increase in the cathode-side oxygen pressure in HT-PEM fuel cells first led to an increase, then to a decrease in the potential of the cell on the other hand they saw an increase while the pressure getting high [4]. Özgür and Yakaryılmaz have combined exergy analysis of PEM fuel cell found that there are many parameters affecting the exergy efficiency of the system [5]. Ramesh P. Duttagupta SP. a two-dimensional interdigitated flow field model was developed to simulate the effect of output channel width on PEM fuel cell performance using COMSOL Multiphysics, and the simulated results were found to fully coincide with the experimental results [6]. Duanghathai Kaewsai et al. ORR activity in the PEM fuel cell of the heat treatment was examined and it was found that the most suitable PtCr/C-500 catalyst to be used in the battery [7]. İçingür and Kireç discussed the effects of pressure, temperature and humidification on fuel cell performance. In the experiments, they obtained maximum 2.19V value from aluminum battery and maximum 3.12V voltage from stainless steel battery [8]. Bilen et al. aimed to design an electrolyser that provides hydrogen production using pure water. The theoretical calculations that increase the amount of hydrogen produced by increasing the distance between electrodes and the electrode surface area in the electrolyser unit were also determined [9]. Yılmaz and Şevik performed H_2 production and performance analysis of fuel cell using $NaBH_4$. 5.6V DC voltage value and 0.3A current value were found in the cell. Efficiency at power and ideal voltage was found to be 41.5% and 82.2% respectively [10]. Çevik at al. showed the effects of different compression pressures on fuel cell performance [11]. Sezgin et al. Comsol Multiphysics 5.0, activation zones at 160°C, the input hydrogen gas velocity was 0.133m/s, while the inlet air velocity 10m/s proton conductivity was 1.3m/s was obtained [12]. Akbar et al. they worked on the materials used in the fuel cell [13]. Cooper et al. examined the effects of channel width and depth on PEM fuel cell performance, and examined various critical cathode flow area dimensions [14].

2. MATERIALS AND METHOD

Pem Fuel Battery Chemistry And Thermodynamic Structure

Electrochemical reactions in the fuel cell take place in two parts of the membrane, anode and cathode layers.

Anode Reaction: $H_2 \longrightarrow 2H^+ + 2e^-$ (1)

Cathode Reaction: $1/2\ O_2 + 2H^+ + 2e^- \longrightarrow H_2O$ (2)

Generally speaking, the two reactions are expressed as total:

$$H_2 + 1/2O_2 \longrightarrow H_2O \quad (3)$$

This reaction shows the basic processes taking place in the fuel cell. Since the combustion in the reaction is exothermic, energy is released. In order to calculate the voltage generated in the fuel cells, the energy must first be explained. It is not possible to achieve full yield during the reaction. Loss of heat occurs due to the lack of full efficiency. Gibbs free energy, which expresses the energy difference between reactants and products and useful energy, is defined as follows.

$$\Delta G = \Delta H - T\Delta S \quad (4)$$

$$\Delta G = (h_f)_{H_2O} - \left(h_f\right)_{H_2} - \frac{1}{2}\,(h_f)_{O_2} \quad (5)$$

S in the Gibbs free energy formula refers to the lost energy (entropy) resulting from the products reacting and formed as a result of the reaction and is given in (6).

$$\Delta S = (h_s)_{H_2O} - (h_s)_{H_2} - \frac{1}{2}(h_s)_{O_2} \quad (6)$$

Electrical work is generally obtained by multiplying the load and potential as shown in (7).

$$W_{el} = q.E \;\; (jmol - 1) \quad (7)$$

The total charge transfer is as follows in the fuel cell reaction.

$$q = n.NAVG.qel \quad (8)$$

In this expression, n represents the number of electrons per molecule (n=2 for H_2), q Coulombs charge, in mol-1 units, and N_A:6.022*10^{23} mol^{-1} [15].

3. EXPERIMENTAL PROCEDURE

In order to observe the effects of parameters such as temperature, humidity, and mass of PEM fuel cell on fuel cell performance, PEM test cell, experimental setup and method are explained. All instruments were assembled to the required places on the test apparatus and the test apparatus was formed. First, one hydrogen cylinder and one oxygen cylinder were provided. These hydrogen and oxygen cylinders were connected to the hydrogen and oxygen flow meters placed in the test apparatus by pneumatic hoses. Hoses were placed at the outlets of the hydrogen flowmeter and oxygen flowmeter so that flow could be realized and hydrogen humidification and oxygen humidification containers were provided. Afterwards, electronic moisture meter devices were installed in the inlets and outlets of hydrogen and oxygen humidification containers. Two thermocouples (steel hoses) were installed at the outlets of the hydrogen humidification and oxygen humidification containers. Electronic thermometers were installed at the inlets and outlets of the hydrogen steel hose and the oxygen steel hose. Outlets of the hydrogen steel hose and oxygen steel hose, connection to the Polymer Electrolyte Membrane (PEM) fuel cell with connection elements to allow the passage of hydrogen gas and oxygen gas into the fuel cell. In Fig. 1 show that representing the experimental diagram.

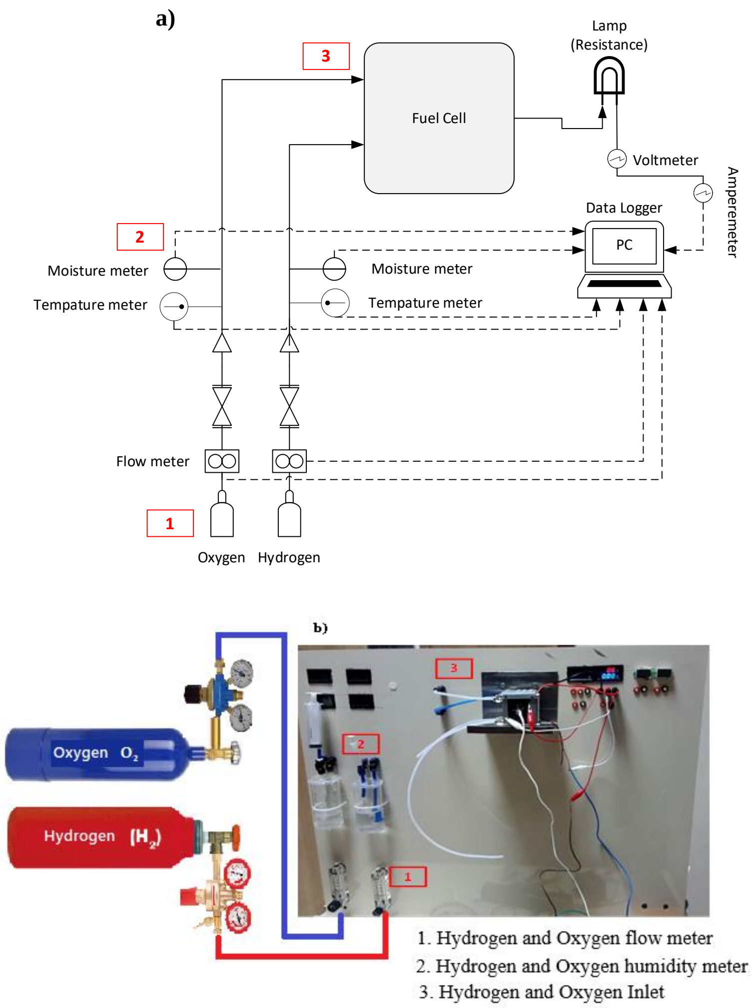

Figure 1. Designed PEM fuel cell prototype

In the operation of the installed test apparatus; first, a certain amount of hydrogen and oxygen gas was introduced into the system from the hydrogen and oxygen gas cylinders. These hydrogen and oxygen gases were passed through the flow meter and hydrogen flow and oxygen flow were measured one by one and brought to the desired values. After the flow rates of the gases were measured, the gases were humidified in the humidification containers we created in the apparatus for both oxygen gas and hydrogen gas. Then, the moisture levels were measured by electronic moisture meter devices that we installed in the inlet and outlet of the humidification containers. Steel hose connection is made to the outlets of humidification containers. Temperature levels of hydrogen and oxygen gases were also measured by thermometers connected to the inlet-outlet portions of the steel hoses of hydrogen and oxygen gases. The gases were adjusted to the desired temperatures and the required values were taken. Then the hydrogen and oxygen gases passing through the steel hoses, the cathode section of the fuel cell oxygen and anode section of the hydrogen gas input was made by adjusting the desired values were sent to the system. Electrochemical reactions in the fuel cell system resulted in electricity generation. The resulting water (H_2O) is discharged from the fuel cell in the form of water. Current values of the system are measured In voltage with voltmeter and ampermeter (measuring instruments).

4. EVALUATION OF TEST RESULTS

As a result of the experiments when the devices and all equipments are ready,

• The temperature value is 40°C.

• The flow rate of H_2 gas is taken as 0.3ml /min.

• O_2 gas flow rate is taken as 0.5ml/min.

The line temperature values in the system are entered to the computer in the range of 40°C - 45°C - 50°C - 55°C - 60°C - 65°C - 70°C - 75°C - 80°C, and the effects of these value ranges on the system performance checked. Fig. 2 shows the change of the voltage values graph according to the temperature value in these value ranges.

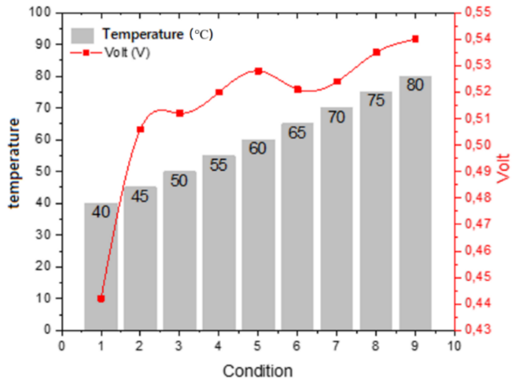

Figure 2. In-system temperature-voltage values

System performance was examined by checking the change of voltage values by taking values between 40°C and 80°C. Similarly, the temperature-amperage values between the lowest temperature of 40 °C and the highest temperature of 80°C were observed.

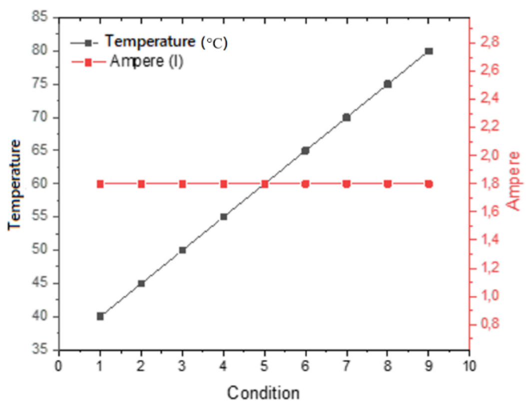

Figure 3. In-system temperature-Ampere values

The temperature values of H_2 and O_2 gases were taken at 40°C - 45°C - 50°C - 55°C - 60°C - 65°C - 70°C - 75°C - 80°C values. At the lowest temperature and the highest temperature current value remained constant in the system. Fig. 4 was generated by taking the power values at the same temperature ranges this time.

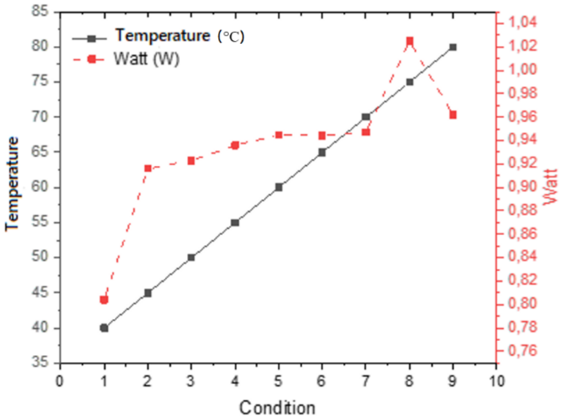

Figure 4. In-system temperature- powers

At these temperatures, the power value at 40°C was measured as 0.804W, while the highest temperature at 80°C for the system was 0.962W. The highest power value was reached at 75°C. The best performance temperature range for the system was observed at 70-75°C. As the temperature increased, it was observed that there was a slight increase in power value and when it was increased to 80°C, system power started to decrease again. Likewise, V values and W values in the system are measured and monitored at certain intervals and their effects on the system are examined and shown in Fig. 5.

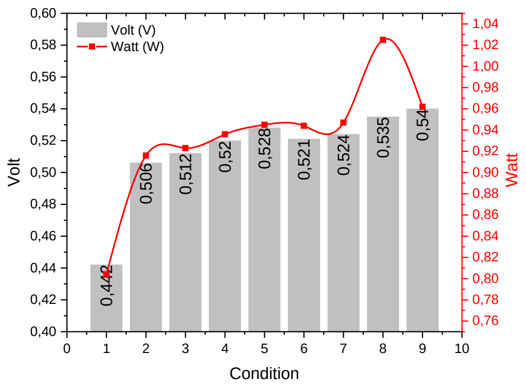

Figure 5. In-system voltage-powers

When the voltage - power graph is examined, the voltage value is 0.804 and the power value is 0.442. Voltage values remained constant after a slight increase in the range of 0.804 to 0.916, increased again in the range of 0.947 to 1.025 and then again in a stable state. At this time, the power value remained stable after a slight increase. When the current values measured during the test setup and the voltage values monitored throughout the system were measured, the values obtained were entered to the computer and the current and voltage graph was created.

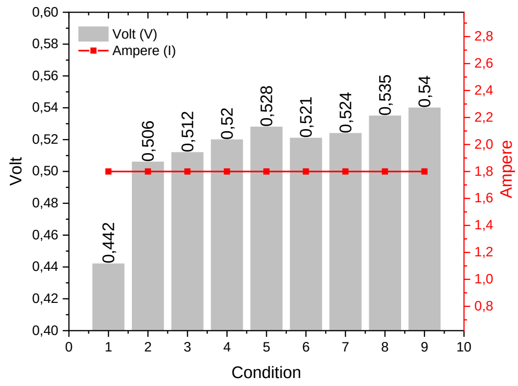

Figure 6. In-system Current- Voltage values

As can be seen in Fig. 6, during the system follow-up, the voltage values increased by a certain ratio, while the current values did not change. The current value measured at the lowest voltage and at the highest voltage is the same.

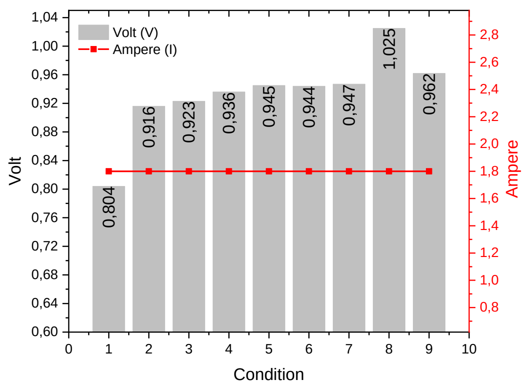

Figure 7. Current-Power values

When the current and W values taken in the system are entered into the computer, the distribution in Fig. 7 has occurred. Amperage values remained constant while changes in W values were observed. After taking the required Temperature, Voltage, Current and Power values, the performances of these data in the system are calculated and shown in Fig. 8.

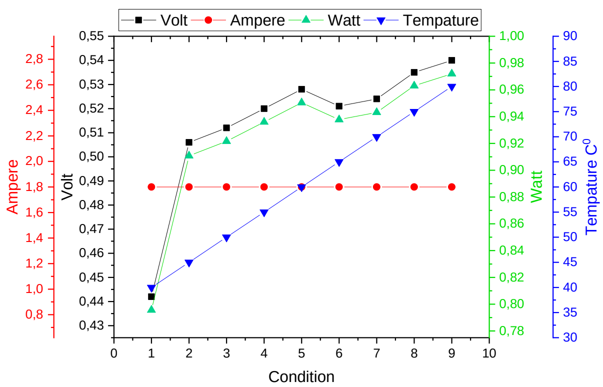

Figure 8. Voltage-Current-Power temperature values

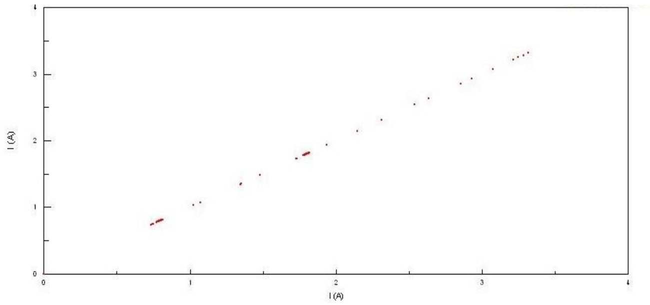

Figure 9. System Temperature Current Values

The temperature, voltages, current and power data obtained from the system were evaluated and the necessary calculations were made and the total graph was created as shown in Fig. 9. When the temperature increased, there was no significant difference in voltages, currents and power values. It has been found that the performance of the system gradually increases if the temperature is increased.

The data obtained from the designed experimental setup were compared by experimenting with another program. Results were observed to be parallel. The visualization of this program is as shown in Fig. 9, Using the fuel cell's own program, the effects of H_2 and O_2 gases on the system performance were investigated.

5. CONCLUSION

The temperatures of the fuels sent to the system were increased to a certain extent and how they affect the performance of the installed system was examined. When the flow rate of H_2 gas is taken as 0.3ml/min and the O_2 gas flow is taken as 0.5ml/min, when the line temperature in the system is 40°C, the current value of 1.81A and the voltage value is taken as 0.442V, It was found to be 0.804W. When the temperature is 40°C, the system has the lowest power value and the system performance is the lowest. When the line temperature of the system was increased to 45°C, the current value was 1.8A and the voltage value was 0.506V, thus the power value was obtained as 0.916W. When the line temperature was increased to 50°C, the system was found to be 1.8A, 0.512V and power rate 0.923W. When the current line temperature in the system is increased to 55°C, the current value is 1.8A, the voltage value is 0.520V and the power value is 0.936W. When the temperature value was increased to 60°C, the current value was 1.8A according to the data obtained from the system, and the power value was measured as 0.945W when the voltage value was measured as 0.528V. When the current was found to be 1.8A and the voltage was 0.521V, the power value was found to be 0.944W at 65°C. Line temperature value at 70°C, current 1.8A and voltage 0.524V power obtained in the system was measured as 0.947W. When the line temperature value in the system is 75°C, the current value is 1.8A and the voltage value is taken as 0.535V, the power value in the system is obtained as 1.025W. Thus, the highest power value was obtained when the line temperature was 75°C. When the temperature value is increased to 80°C, the current value is 1.8A, the voltage value is 0.540V and the power value decreases to 0.962W.

As a result of the experimental study, it was determined that the effect of temperature parameter on the performance of PEM fuel cell was significant. As the temperature increased, system performance increased. It was concluded that there was a slight increase in system performance at temperatures between 40°C and 75°C. However, when the temperature value is increased to 80°C and above, it is observed that the power in the system decreases and the performance decreases.

6. REFERENCES

[1] Strahl, S. & Costa-Castell´o R. (2017). Temperature control of open-cathode PEM fuel cells, *IFAC Conference Paper Archives*, Barcelona, Spain, 11088-11093.

[2] Lee, J., Gundu, M., Lee, N., Lim, K., WooLee, S., SoonJang, S. & YoungKim, J. (2020). Innovative cathode flow-field design for passive air- cooled polymer electrolyte membrane (PEM) fuel cell stacks, *International Journal of Hydrogen Energy*, 45(20), 11704-11713.

[3] Chugh, S., Meenakshi, S., Sonkar, K., Sharma, A., Kapur, G.S. & Ramakumar, S.S.V. (2019). Performance evaluation of PEM fuel cell stack on hydrogen produced in the oil refinery, *International Journal of Hydrogen Energy*, 45(8), 5491-5500.

[4] Søndergaard, S., Cleemann, L.N, Jensen, J.O & Bjerrum, N.J. (2019). Influence of oxygen on the cathode in HT-PEM fuel cells, *International Journal of Hydrogen Energy*, 44(36) 20379 -20388.

[5] Özgür, T. & Yakaryılmaz, A. (2018). A review: Exemplary analysis of PEM and PEM fuel cell based CHP systems, *International Journal of Hydrogen Energy*, 43(38), 17993-18000.

[6] Ramesh, P. & Duttagupta, S.P. (2013). Effect of Channel Dimensions on Micro PEM Fuel Cell Performance Using 3D Modeling, *Internatıonal Journal Of Renewable Energy Research P.Ramesh Et Al.*, 3(2).

[7] Kaewsai, D., Yeamdee, S., Supajaroon, S. & Hunsom, M. (2018). ORR activity and stability of PtCr/C catalysts in a low temperature/pressure PEM fuel cell: Effect of heat treatment temperature, *International Journal of Hydrogen Energy*, 43(10), 5133-5144.

[8] İçingür, Y. & Kireç L. (2011). Design and trials of the gas flow plates in a polymer electrolyte membrane fuel cell, *Gazi University Journal of Polytechnic*, 14(1), 31-34.

[9] Bilen, G., Toklu, E., Avci, A.C., & Gur, M. (2014) Design of a 20 m3/h capacity hydrogen generator by sharp electrolysis method and investigation of the effect of porous electrode materials on parameters, *The Journal of Engineering Research*, 3, 184-195.

[10] Yılmaz, A. & Şevik, S. (2017). Experimental Analysis of Electricity Generation with Sodium Borohydride ($NaBH_4$) Assisted Hydrogen/Air PEM Fuel Cell, *Batman University Journal of Life Sciences*, 7(2/2), 216-227.

[11] Çevik, İ., Coşman, S. & Kahraman, H. (2014). The effect of compression pressure on PEM fuel cell performance, *2nd Internatıonal Symposıum On Innovatıve Technologıes In Engıneerıng and Scıence Sakarya University*, 1008-1016.

[12] Sezgin, B., Caglayan, D. G., Devrim, Y., Steenberg, T. & Eroglu İ. (2016). Modeling and sensitivity analysis of high temperature PEM fuel cells by using Comsol Multiphysics, *International Journal of Hydrogen Energy*, 41(23), 10001-10009.

[13] Akbar, S., Anwar, A., Noon M. Z., Elliott J. M. & Squires, A. M. (2019). Platinum as an electrocatalyst: effect of morphological aspects of Pt/Pt-based materials, *Materials Science and Technology*, 35(1), 1-11.

[14] Cooper, N., Smith, T., Santamaria A. & Park, J. (2016). Experimental optimization of parallel and interdigitated PEMFC flow-field channel geometry, *International Journal of Hydrogen Energy*, 41(2), 1213-1223.

[15] Hirschenhofer, J. H., Stauffer, D. B., Engleman R. R. & Klett M. G. (1998). Fuell Cellll Handbook, *Fourth Edition, DOE/FETC-99/1076, U.S. Department of Energy Office of Fossil Energy Federal Energy Technology Center*.