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A review on performance improvement of flow field design for PEM fuel cell

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ABSTRACT

Due to excess population, demand for fuel gets increased. Air pollution is the major cause of depletion in the ozone layer. In order to overcome this problem, fuel cell is introduced. It is majorly used for power generation which does not emit any harmful gases. The performance of PEM fuel cell based on several forms such as water management, design parameter, channel design. In PEM fuel cell the important issue is water management problem. In order to rectify that issue we used water management concept by changing the design of flow channel. In this review paper, the literature survey has been conducted based on new flow field channel designing and analyzing.

INTRODUCTION

Fuel Cell

A fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. A PEM (Proton Exchange Membrane) cell uses hydrogen gas (H_2) and oxygen gas (O_2) as fuel. The products of the reaction in the cell are water, electricity, and heat. This is a big improvement over internal combustion engines, coal burning power plants, and nuclear power plants, all of which produce harmful by products. Structure of fuel cell is shown in Fig. 1.

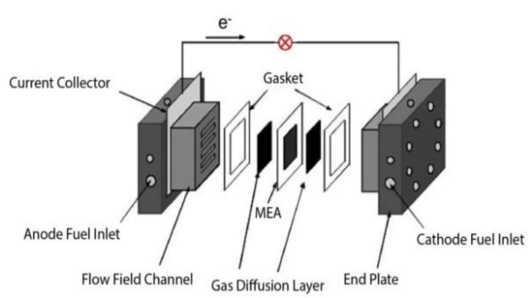

Fig. 1 Structure of Fuel Cell

- Hydrogen, or a hydrogen-rich fuel, is fed to the anode where a catalyst separates hydrogen's negatively charged electrons from positively charged ions (protons)
- At the cathode, oxygen combines with electrons and, in some cases, with species such as protons

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or water, resulting in water or hydroxide ions, respectively

- The electrons from the anode side of the cell cannot pass through the membrane to the positively charged cathode; they must travel around it via an electrical circuit to reach the other side of the cell. This movement of electrons is an electrical current.
- The amount of power produced by a fuel cell depends upon several factors, such as fuel cell type, cell size, the temperature at which it operates, and the pressure at which the gases.

Merits of fuel cell

Zero emission

Fuel cell operates on pure hydrogen, which emits zero emissions at the operation. Based on measured data, a stationary fuel cell power plant creates less than one bounce of pollution per 1,000 kilowatt-hours of electricity produced. Conventional combustion generating technologies create 25 pounds of pollutants for the same amount of electricity. So, the Emissions from fuel cells are very low.

Fuel cells also reduce noise emissions. Since fuel cells do not rely on combustion and have few moving parts, they are very quiet – about 60 decibels, the volume of a typical conversation. Fuel cell electric vehicles (FCEVs) are the least polluting of all vehicle types that consume fuel directly, emitting zero emissions during use.

Fuel cell operation and working condition

Fuel cells are much quieter than many incumbent technologies. This allows them to be sited in places such as parks or residential areas. Most conversation takes place around a noise level of 60 db, which is approximately the noise level measured at 1 meter for all fuel cell units between 1-250 kW regardless of application. When integrated into a system, air pumps and/or fans are typically needed, which are usually the only source of noise on a fuel cell power unit or vehicle.

Classification of fuel cell

Based on the type of Electrolyte

- Alkaline Fuel cell (AFC)
- Phosphoric Acid Fuel cell (PAFC)
- Polymer Electrolytic Membrane Fuel Cell (PEMFC)
- Solid Polymer Fuel Cell (SPFC) and
- Proton Exchange Membrane Fuel cell (PEMFC)
- Molten Carbonate Fuel Cell (MCFC)
- Solid Oxide Fuel Cell (SOFC)

Proton exchange membrane fuel cell

The PEM fuel cell is having high efficiency and operates at atmospheric temperature. So PEM fuel cells are widely used for many applications. PEM fuel cell uses a water-based, acidic polymer membrane as its electrolyte with platinum-based electrodes. PEM1 fuel cell cells operate at relatively low temperatures.

Principle of working – PEM fuel cell

A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and (or air) enters the fuel cell through the cathode. Hydrogen fuel is fed into the "anode" of the fuel cell. Oxygen hydrogen atom splits into a proton and an electron, which take different paths to the cathode. The proton passes through the electrolyte. The electrons create a separate current that can be utilized before they return to the cathode to be reunited with the hydrogen and oxygen in a molecule of water. Working of PEM fuel cell as shown in Fig 2.

Applications of fuel cell

- Power backup, portable applications.
- Consumer electronics personnel computer
- No noise and air pollution
- Waste heat produced can be utilized for other purposes.
- Personnel vehicle engine substitution.
- Fuel cells being incorporated into buses, locomotives, airplanes etc.,
- Lubrication and maintenance problems are eliminated.

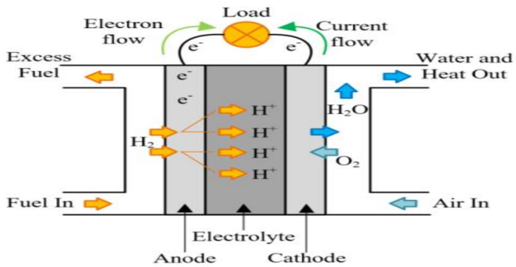

Fig. 2 Working of PEM Fuel Cell

LITERATURE SURVEY

Bukhari Manshoor et al. [1] investigated a straight and serpentine flow field to analyse the effects of changes in the flow field and the performance of fuel cell. The results show that the velocity distributions become more uniform for straight flow field designs when compared to the serpentine flow field designs. The velocity gets affect when changing the flow field. The serpentine flow-field gives more uniform velocity compare with straight flow-field.

Diankaiqiu et al. [2] experimentally investigated efficient design method of flow channels of metallic bipolar plates to improve manufacturing technique of BPPs and maximize power density. The methodology developed is beneficial to the fabrication management of metallic BPPs and effective to the channel design principle for PEM fuel cells.

Ebrahimafshar et al. [3] investigated a new flow field zigzag flow channel with a cooling plate. The cooling plate thickness, channel depth, rib width, channel width and the channels hydraulic diameter are 2mm, 1mm, 2mm and 1.33 mm, respectively. A similar model with 37 parallel paths is also considered for comparison. The performance of zigzag channels model was obtained and about 23%, 5% and 8% reduction was observed, respectively, in surface temperature difference, maximum surface temperatures and uniformity indices, in comparison with straight channels model. The model with zigzag channels has better cooling performance, although the coolant pressure drop is significant in this configuration.

Ebrahimzadeh et al. [4] investigated effect of obstacle dimensions and arrangement of PEM fuel cell. Simulation of different obstacle heights and widths. Obstacles with 0.5, 1, 1.5 and 2 mm heights and 0.9, 1.8, 2.7 and 3.6 mm widths. Results of PEMFC show the height at 1.5mm and width at 3.6 have the high impact of efficiency, pressure drop and current density.

Elifekerkahveci & Imdattaymaz [5] investigated a 3-D, 1-phase proton exchange membrane (PEM) fuel cells with triple-serpentine flow channel numerically on evaluating gas reactant, water management and cell performance. In Three-dimensional model of PEM fuel cell, the following result was obtained; the humidity in the reactant gases is a major factor to consider for improving the cell performance. As the humidity of anode side increases, both the chemical reaction and mass transfer of hydrogen are enhanced due to the increase of water content in the membrane, which leads to a better cell performance. Elifekerkahveci & Imdattaymaz [6] developed the PEM fuel cell model with single serpentine flow channel by using Computational Fluid Dynamics. They developed a three dimensional polymer electrolyte membrane with an active area of 25 cm^2. After successful experiments, it was found that the performance of the PEM fuel cell increased with optimum rise in temperature, but the temperature should not exceed 365 K. It was also found that performance was raised with increase in porosity of the GDL.

Ghanbarian [7] developed and investigated the design of parallel serpentine flow field with an active area of 5×5 cm^2. The result produced the best serpentine type flow field configuration for the given operating condition with geometrical specification as (L, n, s, w, d, h) = (249, 5, 4, 1, 1, and 0.4).

Karthikeyan et al. [8] reported about the optimization of both operating and design parameters. The four models of PEM fuel cell with seven layers like membrane, anode and cathode

GDL, anode and cathode catalyst layers, anode and cathode flow channels were operated at the same operating conditions of 1.5 bar pressure and 50°C temperature. From the results, landing to channel width of 0.5 x 0.5 mm has produced the better performance with peak power density of 0.4473 W/cm^2 and peak current density of 1.1183 A/cm^2 compared to other three designs.

Luis Valino et al. [9] analysed the performance of a cell with cascade flow fields with 100 cm^2 active area. Different configurations in the flow direction were studied counter flow, co-flow and cross flow. The main results showed that the consumption of the reactants on the catalytic layers mainly depends on the gas flow with stoichiometric defect, which is usually hydrogen, and not on the configuration of the flow direction. Distribution of the reactants throughout the flow field yielded non-uniform electrochemical reaction over the catalyst layer. Most of the electrochemical reactions took place near the hydrogen inlet, so that a very significant part of the active area was underused.

Moosa Ashrafi et al. [10] examined a modified Z type flow field of 26.52 cm^2 active area to improve the two phase flow uniformity of parallel flow fields. Many experiments were conducted to find the unsteady distribution of water coverage, cathode stoichiometry ratio and power with z-flow fields. The results showed that power and efficiency are stable at high cathode stoichiometric ratios, but magnitude is low. The flow field was then modified with a 3D numerical model. The simulation results illustrated that the parasitic power for the air supply system of modified Z type flow-field was less than the simple flow-field. Also its overall efficiency was higher.

Muthukumar et al. [11] investigated the 3D models of PEM fuel cell with multi-pass serpentine flow field designs having three, six and nine passes were analysed. The operating parameters and the cross-section of the channel were considered as same for all three designs. The PEM fuel cell models with three, six and nine passes serpentine flow field were analysed numerically with the operating temperature of 323 K at pressure 1.5 bar. The six pass serpentine flow channel yielded more power output compared to other two flow channels.

Nattawutjaruwasupanta & yottanakhunatorn [12] investigated the effects of channel configurations of flow field plates on the performance of a PEM fuel cell. Flow field channel velocities of 1, 2, 3, 4, 5, 6 channels were analysed. The new fuel cell has better performance than old fuel cell about 25%. From the experiment results on 4 channels smooth curve and 6 channels sharp curve, the fuel cell has the density of electric power about 900 and 1200 mA/cm^2 at 0.6 V, respectively. Flow field has 6 channel is 25% better than 4 channels.

Nguyen [13] studied the interdigitated flow field pattern and found that the dead end profile of the flow channel forced the gases to go through the gas diffusion layer and those gases pushed out the water droplets entrapped in the layers of electrode. This also increased the amount of reactants reaching the catalyst layer from the channels leading to increase in performance and the problem of flooding was also reduced. Perng [14] investigated the effect of gas diffusion layer (GDL) on non-isothermal transport characteristics and cell performance of the proton exchange membrane (PEM) by the finite volume SIMPLE-C method coupled with gradient methods. They pointed that compared with flat gas diffusion layer, the prominent gas diffusion layer with N = 7 and HP =0.21 mm prominences enhances the cell net power best by approximately 15.07% among all geometric designs.

Qin et al. [15] proposed the use of hydrophilic plate flow field which increased the water removal rate. A novel flow field design towards the cathode side of the PEMFC is used for efficient water removal. The effect of three flow patterns (conventional serpentine, pin type flow channel with adoption of porous carbon inserts in uniform and zigzag pattern) has been studied numerically and their performances have been compared. Tao Chen et al. [16] investigated the impact of bionic flow field for PEM fuel cells using different branching structure. The location of branches plays a vital role in exit velocity, which is an impact on discharge of water. The result showed that the flow field patterns had a greater impact with the lower voltage of 0.7V at high current densities. The new Biomimetic flow field gave more gas consumption ratio and more uniform gas distribution ratio than the conventional flow field.

CONCLUSION

In PEM fuel cell, the important issue is water management problem. In order to increase the performance of PEM fuel cell, different flow channel design results were optimized and analyzed in above literature survey papers. The examined result shows that various flow field channel design provides better output voltage when compared to one another. The velocity distributions become more uniform for straight flow field designs when compared to the serpentine flow field designs. The velocity gets affected when changing the flow field. The serpentine flow-field gives more uniform velocity compared with straight flow-field.

REFERENCES

[1]. Bukhari Manshoor, Lailyazwati Mohamed Ster, Amir Khalid and Izzuddin Zaman, 'An effect of straight and serpentine flow field designon proton exchange membrane fuel cell'-EDP Sciences, 12, 2017, 1819-6608.

[2]. Diankaiqiu, LinfaPeng, Peiyun Yi, Xinmin Lai, Werner Lehnert, 'Flow channel design for metallic bipolar plates in proton exchange membrane fuel cells: Experiments' - Energy Conversion and Management, 174, 2018, 814–823.

[3]. Ebrahimafshar and Mehdi Musharraf Dehkordi 'Numerical investigation on a novel zigzag-shaped flow channel design for cooling plates of PEM fuel cells' – Journal of the Energy Institute, 90, 2017, 752-763.

[4]. Ebrahimzadeh A A, Khazaee I, Fasihfar A, 'Numerical investigation of dimensions and arrangement of obstacle on the performance of PEM fuel cell'-heliyon, 4, 2018, 2405-8440.

[5]. Elifekerkahveci, Imdattaymaz 'A Three-Dimensional Model of Single PEM Fuel Cell Having Triple-Serpentine Flow Channel Developed with CFD'- Journal of Development Research, 2, 2017, 1238-1242.

[6]. Elifekerkahveci, Imdattaymaz, 'Assessment of single serpentine PEM fuel cell model developed by Computational Fluid Dynamics'- Fuel, 217, 2018, 51-58.

[7]. Ghanbarian A, Kermani M J, Scholta J, Abdollahzadeh M, 'Polymer electrolyte membrane fuel cell flow field design criteria – Application to parallel serpentine flow patterns'- Energy Conversion & Management, 166, 2018, 281-296.

[8]. Karthikeyan P, Muthukumar M, Vignesh Shanmugam S, Pravin Kumar P, Suryanarayanan Murali and Senthil Kumar A P 'Optimization of Operating and Design Parameters on Proton Exchange Membrane Fuel Cell by using Taguchi method' – International Conference on Design and Manufacturing ,64, 2013, 409 – 418.

[9]. Luis Valino, mustataradu, Isabel Gil Marıa, Martın Jesus, 'Effect of the relative position of oxygen-hydrogen plate channels and inlets on a PEMFC'- International Journal of Hydrogen Energy, 35, 2010, 11425-11436.

[10]. MoosaAshrafi, Homayoonkanani, Mehrzad Shams, 'Numerical and experimental study of two-phase flow uniformity in channels of parallel PEM fuel cells with modified Z-type flow-fields'- Energy, 147, 2018, 317-328.

[11]. Muthukumar M, Saravanaperumal S and Senthil Kumar A P 'Effect of Multi-pass Serpentine Flow Field Designs on the Performance of Proton Exchange Membrane Fuel Cell' - International Journal of Applied Engineering Research,10, 2015, 22429 – 22435.

[12]. Nattawutjaruwasupanta and yottanakhunatorn 'Effects of difference flow channel designs on Proton Exchange Membrane Fuel Cell using 3-D Model'-Journal of energy and material science, 6, 2011, 326-337.

[13]. Nguyen TV, 'A Gas Distributor Design for Proton-Exchange-Membrane Fuel Cells'-Journal of Electrochemical Society, 143, 1996, 103-105.

[14]. Perng, Shiang-Wuu, Horng-Wen Wu, and Gin-Jang Shih 'Effect of prominent gas diffusion layer (GDL) on non-isothermal transport characteristics and cell performance of a proton exchange membrane fuel cell (PEMFC)'- Energy, 88, 2015, 126-138.

[15]. Qin Y Z, Li X G, Jiao K, Du Q and Yin Y, 'Effective Removal and Transport of Water in a PEM Fuel cell flow Channel Having a Hydrophilic Plate'-Applied Energy, 113, 2014, 116-126.

[16]. Tao Chen, Yong Xiao and Tiezhu Chen 'The impact on PEM fuel cell of bionic flow field with a different branch' - Science and technology, 28, 2012, 134 – 139.