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REVIEW ARTICLE

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PARAMETERS INFLUENCING THE PERFORMANCE OF PEM FUEL CELL – A REVIEW

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ABSTRACT

Proton exchange membrane fuel cell (PEMFC) is an electric energy producing device. Its performance depends not only on many factors, including the conditions of operation, the kinetics of the electrochemical reactions and transport phenomena inside the cell, but also in its membrane conductivity, water management, flow field and design parameters. Among the PEM stack components, membrane electrode assembly (MEA) and flow field are considered one of the crucial ones, as they provide one of the most essential issues regarding the performance improvement. In this paper Water management in PEM fuel cells reviewed briefly. If the management is not in a proper manner, failure will occur and performance will be influenced by the above mentioned factors. The aim of this work is to review the most important results carried out in recent years related to the influence of water transport by flow channel, membrane conductivity of hydrogen, diffusion layer properties and design parameters on the overall performance of a PEMFC. It is concluded that the controlling of flow field design and membrane conductivity can improve the performances of PEM fuel cell.

Keywords : membrane conductivity, water management, flow field, design parameters

INTRODUCTION

Proton exchange membrane fuel cell is also called as polymer electrolyte membrane fuel cell. It is a device used to convert the chemical energy into electrical energy. It consists of parameters such as membranes, flow channel land diffusion layers which are the main components of PEM fuel cell. Enhancing the fuel cell power is the major problem, because the operating conditions, membrane conductivities, flow channel geometries and gas diffusion layers cause the poor performance of the PEM fuel cell.

Apart from the effect of operating parameters and flow field design, the performance of the PEMFCs is significantly influenced by the water management issue. To maintain high electrolyte ionic-conductivity, adequate water must be presented for ensuring appropriate performance. However, if excessive water is present in the liquid phase, it can obstruct the pores in GDLs and the catalyst, which hinders the transport of reactants to the catalyst. Thus, proper water management is surely essential for improved fuel cell performance. Reviewed papers are categorized into following topics, they are water management, review on performance, membrane conductivity, flow field, design parameter.

WATER MANAGEMENT

Suthida Authayanuna et al. [1] studied the effect of water transport on the electrical performance of PEM fuel cell. They had proved that the performance of PEMFC can be increased when increasing operating temperatures. Increasing the humidity of the air and fuel gas leads to a considerable improvement of cell performance. The Presence of the water flooding increases with increasing operating current density. Variation in key operating parameters leads to better understanding and optimal design of cell performance.

Pablo Martins Belchor et al. [02] investigated the water management in a proton exchange membrane fuel cell using a parallel serpentine-baffle flow field plate (PSBFFP) design when compared to the parallel serpentine flow field plate (PSFFP). Low water content is proposed using a parallel serpentine-baffle flow field plate (PSBFFP) design when compared to the parallel serpentine flow field plate (PSFFP). When fitted with the PSBFFP, under low humidification conditions the PEMFC prototype gives better performance. PEMFC prototype performance was monitored by determining the power curves voltage and, current density. Fuel cell must have a good performance when equipped with the designed PSBFFP plates and operated under the latter conditions.

J.P. Owejan et al. [03] studied the Effects of diffusion layer properties and flow field on water accumulation in a PEM fuel cell. By this work neutron radiography method was used to attain two-dimensional distribution of liquid water in operating 50 cm^2 fuel cells. When variations are made of diffusion media properties and flow field channel to assess the effects on the spatial distribution and overall volume of accumulated water. Flow field channels with hydrophobic coating retain additional water, but the allocation of a larger number of smaller slugs in the channel area improves fuel cell performance at high current density. The volume of accumulated on the morphology of water droplets and water retained in the flow field channels having appreciable effects of both Channel geometry and surface property. Cells constructed by means of diffusion media with lesser in-plane gas permeability tended to retain less water.

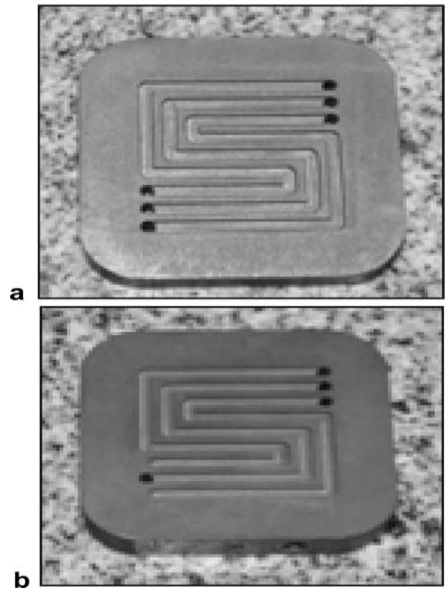

Fig.1 Image of the graphite plates. (a) PSFFP and (b)PSBFFP

Drawn from [02].

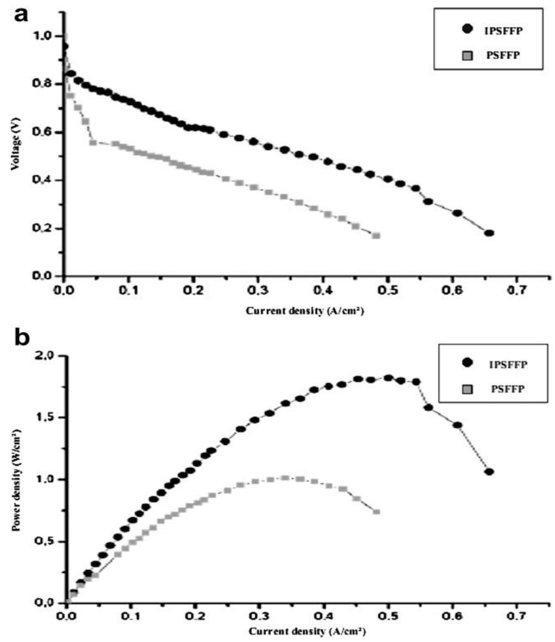

Fig. 2 (a) Current density vs voltage curve curve (b) current density vs power of the PEMFC unit equipped with PSFFP (d-d) and PSBFFP (dCd).

Hideki Murakawal et al. [04] Using neutron radiography visualized the water accumulation process in polymer electrolyte fuel cell. For the purpose of visualization, the water distribution in a small fuel cell was calculated in the through-plane direction by neutron radiography. Nine parallel gas channels with a PEFC were used to distinguish the water accumulated in the GDL under the lands and channels at room temperature. The water accumulations in the GDL under the lands are larger than that of below the channels during the stage of early PEFC operation. Finally, they visualized the condensation was easy to occur in the GDL under the land.

REVIEW ON PERFORMANCE

Ishwar Prasad sahu et al. [05] analyzed the performance of PEM fuel cell under different landing condition. From this analysis various operating parameters affect the output parameters such as efficiency, voltage and power output of the fuel cell. Voltage and efficiency decreased when increasing current density and temperature. The 50°c temperature gives a power output six times than the 30°c temperature. The polarization curves for two kinds of electronic loading such as constant current mode and constant power mode was obtained. Low heating and high heating values of hydrogen was exposed experimentally 119.93kJ/g and 141.86kJ/g respectively. Various characteristic curves such as voltage vs current density, Power vs current density, Current vs hydrogen flow, Efficiency vs current density, Efficiency vs. temperature , Efficiency vs pressure

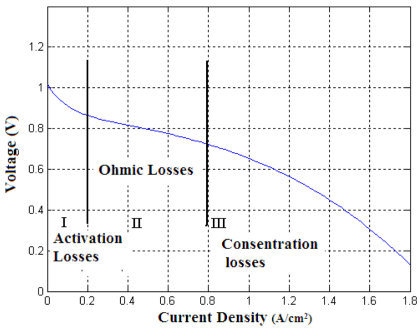

Fig.3 Polarisation Curve [05].

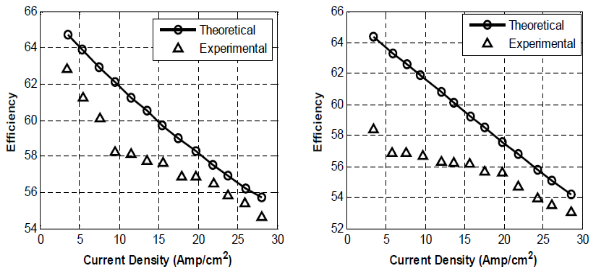

Fig.4 Curve for Constant Current and Power mode [05].

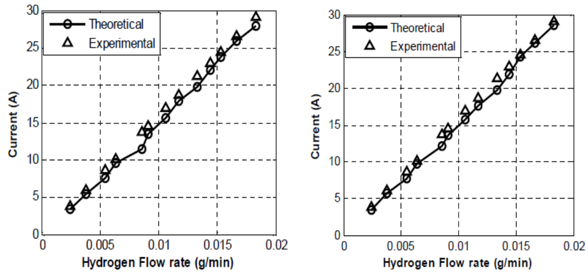

Fig.5 I-m° Curve For Constant Current and Power Mode [05].

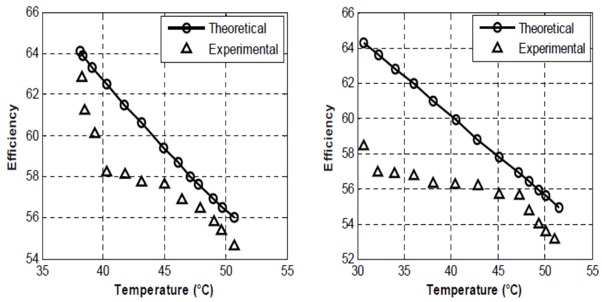

Fig.6 Δ-T Curve For Constant Current and Power Mode [05].

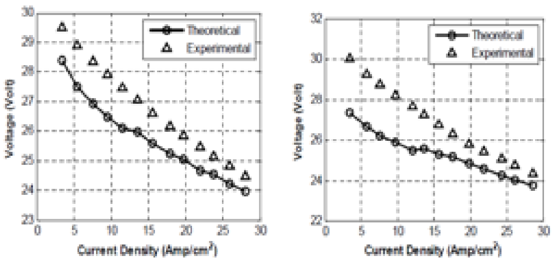

Fig.7 V-I Curve for Constant Current and Power mode [05].

M. ElSayed Youssef et al. [06] Analyzed the Development and Performance of PEMFC Stack based on bipolar plates fabricated employing different designs. A single, two cells, 6 cells and 11 cells LT-PEMFC stack was investigated with cell active area 114 cm2, Nafion membrane 112 and catalyst loading 0.4 mg/cm2 working at 25° C and atmospheric pressure using air and hydrogen as a fuel and oxidant, respectively. The power output that is obtained from each stack is presented and the overall power output is compared with solitary cell stack. The test was carried out with H_2 at anode and air at cathode side with stoichiometric ratios 2 and 1.2, in that order. Stacks were tested at room Temperature. The stack has a maximum power of 71 W at 170mA/cm2 with 11 cells stack rature.

M. Perez-Page and V. Perez-Herranz [07] studied the Performance of a PEM Fuel Cell Stack on Dead-End method by the Effect of Operation and Humidification Temperatures. From this study the performance of PEM fuel cells is influenced by several parameters such as humidification and operation temperature. To monitor and control a 300W fuel cell stack a test bench was developed. The tafel slope decreases with the operating temperature for a given humidification temperature. Due to the membrane conductivity and improvement of the gas diffusivity at higher temperatures the resistance decreases with the operation temperature, when the membrane is very well humidified. Therefore, when the operation temperature is high, higher humidification temperatures are required.

MEMBRANE CONDUCTIVITY

Alin C. Farcas and Petru Dobra [08] studied the Adaptive control of membrane conductivity of PEM fuel cell. By this study the control strategy is implemented by means of 2 PIDs with straight gain scheduling of the controllers coefficients as a function of the temperature. Membrane conductivity in a PEM fuel cell which influences the main part of the current/voltage polarization curve of the cell and the control of conductivity is essential for stable operation and good performance of the cell. Simulated results have shown that the water vapor pressures are controlled accurately and with respect to density current variations the conductivity is constant.

Chen-Yu Chen et al. [09] investigated the Reformate Gas about Behavior of a PEM Fuel Cell. The fuel cell performance is influenced by the nitrogen concentration, operational current and carbon monoxide concentration for a PEM fuel cell which uses PT/Ru the same as the anode catalyst. It drops significantly at a high operational current in hydrogen containing little CO. Results show that the effect of nitrogen dilution improves the poisoning effect of carbon monoxide in the reformate gas.

Odne S. Burheim et al. [10] studied about the thermal conductivity of catalyst layers in PEM fuel cell. From this investigation, they proved that the Dry CLs, and CLs with low water content, were found to have thermal conductivity values of 0.07-0.11 $WK^{-1}m^{-1}$, when condensed in the range of 5-15 bar compaction pressure. When adding the water up to 70 moles of water per mole of sulphonic group, it was observed that, with water content significantly beyond the capacity of the ionomer, water only had an effect on the thermal conductivity. When allowing water to condense onto the catalyst layers, the ionomer. Became residual water and over saturated with water was found in the catalyst layers. The thermal conductivity value can be expected to increase by 50% for these “supersaturated” CLs, when the CL consists of equivalent amount of catalyst nanoparticles and Nafion.

FLOW FIELD

Saif Almheiri et al. [11] revealed the variations in Current density under land and channel in DMFCs. For identifying the current density variables a novel MEA technique is used under the land and under the channel separately. Performance having the drastic difference is recognized to the much higher electrochemical active area (ECA) as indicated by CO stripping voltammetry measurements under the land. From this experimental investigation, they show that, due to the higher *ECA* under the land current density under the land is appreciably higher than that of the channel.

Muthukumar et al. [12] studied the performance of PEM fuel cell with 2, 3 and 4 pass serpentine flow field designs. The performance of the PEM fuel cell governed by the geometrical and flow parameters. Reactants uniformly distributed throughout the active area of fuel cell by flow channels. Maximum power density was obtained as 0.46333, 0.46399 and 0.46336 w/cm2 for 2 pass, 3 pass and 4 pass designs respectively, when the fuel cell models were operated at the cell voltage of 0.35 v. Numbers of passes in the serpentine flow field yields almost same power density. In future, the operating parameters of the fuel cell like temperature, pressure etc. can be varied and their effects can be studied in detail.

Jeffrey Glandt et al. [13] modeled the effect of flow field design on the performance of PEM fuel cell. Computational Fluid Dynamics (CFD) software is used to predict the effect of changes in the flow field geometry and to enlarge a mathematical three-dimensional model of a single PEM fuel cell. Local temperature and current density distributions become more consistent for serpentine flow field designs with a bigger number of passes. Flow-field - affect the current density distribution and also its performances. The double pass flow-field gives more uniform current density distribution and less condensed liquid water on the cathode than the single pass flow-field.

Rodolfo Taccani and Nicola Zuliani [14] investigated about the high temperature PEM fuel cells on effect of flow field design on performances. From this investigation, 5 step serpentine gives best performance also it induces an higher pressure drop transversely the cell. Whilst using parallel channels the performance decreases, but pressure drop is reduced as the current density increases. Further performance improvement can be expected by optimizing the width of the ribs and channel aspect ratio. A comparatively low loss of performance with high CO content fuels was measured.

Arvay et al.[15] studied the nature inspired flow field designs for proton exchange membrane fuel cell. By this study, they found the nature inspired designs can show improved fuel cell performance over standard designs by reducing drop of pressure and promoting uniform gas distribution. This is true when naturally enthused designs are used in grouping with standard interdigitated designs. There is much more work to be done in the areas of new design creation of nature inspired and flow field designs, design evaluation, they have incredible potential to become the new standard for performance of the fuel cell, reliability and cost.

Boris Chernyavsky et al. [16] numerically investigated the flow field in PEM fuel cell stack headers. From this investigation, they have used the numerical simulation approach to model flowfield in the outflow and inflow headers. From this approach they investigated the effects of flow disturbances in the headers on stack performance. Between individual cells and the extent of fleeting variation in the flow rates through individual cells flow rate differences are investigated due to disturbances in the headers. Their results proven that, the outlet header flow field is highly vortical and substantially unsteady. Results indicated, for U- and Z-stack configurations between individual cells are significantly dissimilar patterns of flow sharing.

Nattawut Jaruwasupant and Yottana Khunatorn [17] using 3-D design modeled the effects of the difference flow channel on PEM fuel cell. In this research to predict velocities distribution and pressure drop, a 3-D numerical modeling presented. From that result, The best channel curvature from gas distribution is 6 channels serpentine and sharp curve because it has the higher area of gas flow and secondary flow, pressure drop and elevated velocity when compare with channel length. Fuel cell with our flow field provides enhanced performance. From the experimental results on 6 channels sharp curve and 4 channels smooth curve, there are found that, fuel cell have the density of electric power about 1,200 and 900mA/cm^2 at 0.6 V, respectively. From the results they had proven that the 6 channel Flow field is 25% better than 4 channel Flow field.

DESIGN PARAMETER

Muthukumar et al. [18] optimized the Operating and Design Parameters on Proton Exchange Membrane Fuel Cell by using Taguchi method. The performance of the Proton Exchange Membrane Fuel Cell (PEMFC) is greatly influenced by the various operating parameters and geometric properties. Both operating and design parameters, namely cell temperature, back pressure, cathode and anode inlet velocities, flow channel dimensions, Gas Diffusion Layer (GDL) porosity and thickness, cathode water mass fraction, rib width and porous electrode thickness. When applied taguchi method to experiments, gives better results with fine tuned optimization. In real time applications, fuel cell must be worked with these operating parameters and optimum design to get enhanced performance.

Mingyan He et al. [19] produced the method of overlapping domain decomposition for a polymer exchange membrane fuel cell model. They studied the overlapping domain decomposition finite element method for a simplified two-dimensional single-phase PEMFC model to deal with the non-matching grids. Numerical experiments reveal that our methods are capable to deal with PEMFC simulation on the low mass balance error and non-matching grids with fast convergence. They studied the derived discretization scheme for two-phase unsteady and/or fuel cell stack model in our further work.

Magdalena Bosomoiu et al. [20] studied the fresh and aged gas diffusion layers about effective transport properties. Generally for the diffusion of reactants and the removal of product water, gas diffusion layers (GDLs) plays an important role in PEM fuel cell. The electrical conductivity is quite different at the in-plane and through the plane. Overall, it was shown that the degree of compression plays a significant role on the electrical and thermal conductivities of the GDL. They had proven that the calculated material bulk properties could be next used as input for CFD modeling of PEM fuel cells where GDL is usually assumed homogeneous and layer-like.

CONCLUSION

This review that, the geometric parameters of the flow fields, membrane conductivity and design parameter can have great influence on the overall PEM fuel cell behavior. Many of the PEMFC drawbacks discussed here may be overcome by properly choosing the flow field design. Low water content is proposed using a parallel serpentine-baffle flow field plate (PSBFFP) design when compared to the parallel serpentine flow field plate (PSFFP). Nine parallel gas channels with a PEFC were used to distinguish the water accumulated in the GDL under the lands and channels at room temperature. Membrane conductivity influences the main part of the current/voltage polarization curve of the cell and the control of conductivity is important for stable operation and excellent performance of the cell.

Therefore, flow field design, membrane conductivity is crucial for achieving elevated performance of the PEM fuel cell. Thus, problems in conductivity, water management, and design parameter of reactants can be solved by efficiently design the BP flow fields and so, increase PEMFC performance.

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