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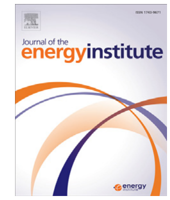

Comparison of perforated and serpentine flow channel plates on the performance of proton exchange membrane fuel cell

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Flow channel design is a significant criterion that affects the performance and water transport characteristics of Proton Exchange Membrane Fuel Cell (PEMFC). In this study, a perforated flow field plate is designed and fabricated to improve the performance of PEMFC in comparison with conventional serpentine channel. This perforated flow field is designed in such a way that it consists of numerous holes of 2 mm diameter in a regular pattern on the entire active area of 25 cm^2. The effect of perforated flow field on the cell performance at various relative pressures of reactants are evaluated and compared with the conventional single pass serpentine flow channel. The experimental results show that perforated flow field delivered a peak density of 242 mW/cm^2 whereas with serpentine flow channel a maximum power density of 230 mW/cm^2 is achieved. On comparison with serpentine flow channel, the perforated flow field showed an *increase in power density* of about 5.8%, 6.5% and 5.2% at relative pressures of 0, 0.5 and 1 bar respectively. Further, the cell impedance test reveals that the cell with perforated flow field shows least impedance. The conductance of the flow plates have been calculated and found to be almost equal for both perforated and serpentine channel geometry.

1. Introduction

Fossil fuels are a form of non-renewable source of energy and they are the driving force in many sectors like power generation, automobile etc. Since their quantity remains to be finite, work on alternate fuel for powering the future is very active in the recent times. One such alternate fuel is hydrogen and the technology is fuel cell. Many types of fuel cell exist, out of which Proton Exchange Membrane Fuel Cell (PEMFC) is most suited for the automotive and stationary applications because of its low operating temperature and high current density. The main barriers for the commercialization of PEMFC are cost of its materials, fluctuating performance and relatively shorter durability of the system.

The performance of the PEMFC depends upon various operating and geometric parameters like cell temperature, back pressure, anode and cathode flow rates, gas diffusion layer (GDL) porosity and thickness and flow field design [1]. Of all these parameters, the design of flow channel has the greater impact on the cell performance [2]. Many numerical and experimental studies conclude that serpentine flow channels are better in achieving overall cell performance by effectively transporting the by-product. Ferng Yuh Ming et al. [3] analyzed the effect of different flow field channels in a 25 cm^2 single cell PEMFC and concluded that serpentine flow field channel is superior in performance. Even though serpentine flow channel is better when compared to other flow channel design, it has certain draw backs like high pressure drop and lower velocity of the reactants passing through the channel [4]. *Xiao-Dong Wang* et al. [5] *proved* that the decrease in flow channel aspect ratio increases the reactant inlet flow velocity, which enhances liquid water removal and increases oxygen transport to the porous layers. Manso et al. [6] concluded that at higher operating voltages, the cell performance is improved as the channel cross-section aspect ratio increases. *Xiao-Dong Wang* et al. [7] *proposed* a novel serpentine baffle flow channel design and compared its performance with conventional serpentine flow channel. They concluded that both the designs have the same performance at higher operating voltages. However at lower operating voltages, the baffled design showed better performance than the conventional serpentine flow channel, the

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reason being that the under rib convention in case of baffled design increases the mass transport rates of the reactants and products. *Dutta* et al. [8] *developed a numerical model for the serpentine flow channel and predicted the velocity distribution, the gas-mixture distribution and reactant consumption on the membrane electrode assembly. They concluded that in both anode and cathode serpentine flow channel plates, the flow distributions of reactants are significantly affected by the mass consumption patterns on the membrane electrode assembly (MEA). Jaewan Park and Xianguo Li* [9] *found that the cross flow of reactants between the adjacent channels through GDL, improves the water removal and reduces the pressure drop in serpentine flow channel. In case of serpentine design, if the channel length is too long, it would lead to substantial pressure drops and decrease the reactant concentration even though there are advantages by the cross flow of reactants. Perforated design relatively has lesser pressure drop since this design has no sharp ends as seen in serpentine channel.*

In a micro scale fuel cell, a similar kind of work was done on serpentine and perforated flow channels by Shou-Shing Hsieh and Yih-Wen Su [10]. They have studied the performance of PEMFC, by trying out different configurations between serpentine and perforated channel designs on anode and cathode flow plates (serpentine/perforated, serpentine/serpentine and perforated/perforated) and concluded that perforated flow channel on anode side performs better with higher energy efficiencies. Despite the advantages like the good water removal capability and high channel velocity found in serpentine flow channel; the reactant flow in them is not relatively much easier to move around due to the too narrow passage design. On a micro fuel cell it has been proved that, at the anode side when perforated flow field design is used, it results in more uniform distribution of fuel than that of the serpentine. To ensure the reliability on scaling up studies (increasing the active area) and to assess the practical feasibility of perforated design, the present work has been carried out on an active area of 25 cm^2. In this work, the performance of the perforated flow field in macro size is experimentally investigated at various relative pressures and compared with serpentine flow channel.

There are various techniques like stepping up potential, sweeping of potential or potential sweeping, electrochemical impedance spectroscopy (EIS) and current interrupt which can be employed to study the transient responses of fuel cell [11]. Generally for characterizing the fuel cells and its components a current or voltage is applied and its corresponding responses are observed. In order to measure the transport properties like the ionic conductivity of the membrane and to measure the ohmic resistance of the fuel cell [12,13] EIS technique is most sorted one among all other techniques. It can be used to detect both single cell and stack impedance.

Recent studies from the EIS results state that ohmic losses can be reduced by using thinner electrolyte membranes with proper humidification, using the materials having better conductivity, using proper design of the flow field and minimizing contact resistances at various interfaces [14]. Yutaka Tabe et al. [15] investigated the effect of channel type and open type cathode separator in detail through cell impedance measurement and concluded that the channel type cathode separator can maintain low contact resistance than the open type cathode separator. Similarly in this paper the impedance of the cell with perforated and serpentine flow channel has *been measured from 10 μHz to 10 kHz using EIS technique* and the results obtained are analyzed. The conductance of the perforated and serpentine flow channel plates are calculated based on its geometry and the values obtained are compared. The aim of this study is to analyze the effect of perforated flow field on the cell performance and to compare the results with serpentine flow channel.

2. Design of perforated flow field plate, end plates and current collector plates

Fig. 1 (a) and (b) shows the channel design of perforated and serpentine being machined on individual graphite plates for an active area of 25 cm^2. For the fabrication of perforated design, holes of 2 mm diameter are drilled on the plate with 2 mm spacing between the holes. On the entire active area of 25 cm^2 (5 cm $\times$ 5 cm), total of 169 holes are made consisting of 13 holes in each row and column. The reactant gas tends to flow through the perforated holes simultaneously to reach the reaction sites. The performance of the PEMFC with this perforated design is experimentally compared with a single pass serpentine flow channel (landing to channel ratio – 2:2).

The end plates used for both perforated and serpentine flow channel designs are of same size (11 cm × 11 cm × 1.5 cm) and material (aluminum). Fig. 2 *(a) and (b) shows the end plates used for perforated and serpentine flow channel respectively. The end plate design of perforated flow field plate differs from that of the one used in serpentine design. The end plates for perforated flow field plates are designed in such a way that, the reactant gas first enters a rectangular space having a volume of 18 cm^3 (6 cm × 6 cm × 0.5 cm).* Due to continuous flow of reactant gas from the source, the pressure in the constrained space gets increased and as a result the reactant gas will start to flow through the holes of the perforated flow plate and diffuses through the GDL to reach the catalyst site. Gaskets are provided between the end plates and current collector plates to avoid leakages of reactants. The inner face of the end plate is completely laminated with an insulating sheet to prevent

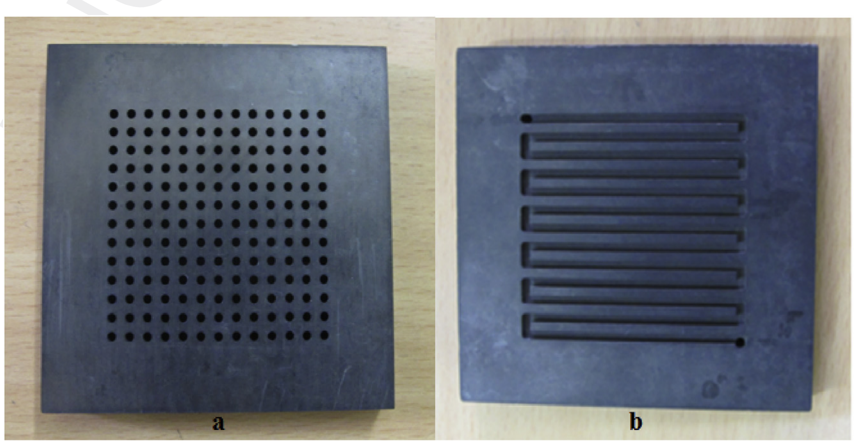

Fig. 1. (a) Perforated flow field plate with 169 holes of 2 mm diameter (b) Serpentine flow channel plate with LxC = 2 × 2.

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