Effect of Manifold and Distributor Dimensions on Flow Characteristics in PEM Fuel Cell Stack

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Abstract. The dimensions of the manifold and distributor in a Proton Exchange Membrane (PEM) fuel cell stack play a crucial role in determining the flow characteristics, which can significantly impact the performance and efficiency of the fuel cell stack. In the present study, the velocity distribution, pressure drop in both manifold and distributor is numerically studied on anode side of a 5 cell stack with serpentine channel design. Four study cases with different manifold diameter and distributor width named as 4 mm x 2mm (case 1), 4 mm x 3 mm (case 2), 6mm x 2 mm (case 3) and 6 mm x 3 mm (case 4) is considered for the evaluation. Among the designs, the case 3 manifold and distributor combo delivered better velocity and pressure drop across the flow field. The equal velocity at the distributor entrance and flow channel entrance made the flow uniform throughout the channels in the active area.

Keywords: PEMFC; uninform flow; manifold; distributor; velocity distribution

1 Introduction

A Proton Exchange Membrane Fuel Cell (PEMFC) stack is a clean energy technology which could potentially replace the fossil fuel resources for power generation. As a type of fuel cell, it operates on the principle of electrochemical reactions to convert chemical energy directly into electrical power. PEMFC is known for its high power density, quick start up times and suitability for various applications, including transportation, stationary power generation and portable devices [1]. In order to operate the fuel cell stack efficiently the uniform reactant supply and product removal from the stack is highly important. The reactant supply to each cell of the stack ensures better stack efficiency. The manifolds at inlet and outlet of the stack plays a crucial role on supply of reactants to both anode and cathode side of individual cells and simultaneously removes the excess reactants and product water from stack [2]. The manifolds are designed in such a way that the pressure drop in manifold should be an order of magnitude lower than the pressure drop observed in flow channels. Along with pressure drop, flow velocity is also an important parameter to be considered

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to avoid internal leakage and to eliminate the reactants gets mixed inside the stack [3]. The manifold can either be internal or external and the flow pattern followed in the stack are U and Z type in general [4]. The hole for manifold is often designed as circular, rectangular and square in shapes [5]. Apart from manifold design the design of the distributor which connects the manifold and each flow channel of the stack also received higher attention from research community for effective transport of reactants [6]. The shape and dimension are two vital factors upon design the manifold and distributor Many research studies reported with different manifold shape and dimension in order to ensure the better reactant distribution. Lebeak et al [7], observed jet flow behaviour when the circular geometry changes to rectangular when entering to manifold which causes the flow maldistribution. The more flow distribution in the final 20% of the channels than initial channels due to high velocity [8], reducing channel hydraulic diameter and increasing the manifold dimension [9], reducing channel width and increasing pressure drop [10], providing double inlet and outlet manifold configurations [11] are some of the findings for flow distribution in manifold as well as in flow channel. This work emphasis the effect of manifold and distributor dimension on anode side of a 5-cell stack with serpentine flow field. The flow velocity in manifold and distributor and pressure drop in flow channel are numerically evaluated and the best combination is identified.

2 Methodology

2.1 Geometry model

The anode compartment of a 5-cell stack is considered for the analysis. Four different combinations of manifold diameter and distributor width viz 4 mm x 2 mm (case 1), 4 mm x 3 mm (case 2), 6 mm x 2 mm (case 3) and 6 mm x 3 mm (case 4) are analysed. In all cases, the width and depth of flow channel is taken as 2 mm and 1.25 mm respectively. Fig.1, shows the 5-cell anode channel and flow channel with aforesaid cases 1 to 4. The active area is assumed as 66 cm2. The channel dimension and fluid properties are given in table 1.

2.2 Mathematical model

A three dimensional model is solved for continuity and momentum equation to analyse the flow characteristics. A few assumptions like steady flow; ideal gas behaviour of reactants and laminar flow are considered. The governing equations used are provided as follows. Continuity equation.

$$\nabla.(\rho) = 0 \tag{1}$$

Where ∇ and u are density and velocity for mass conservation Momentum equation.

$$\rho(u.\nabla)u = \nabla.[-P + K] \tag{2}$$

$$K = \mu(\nabla.u + (\nabla.u)^K) - \frac{2}{3}\mu(\nabla.u)I \tag{3}$$

Where P K and μ are the pressure stress tensor and dynamic viscosity respectively.

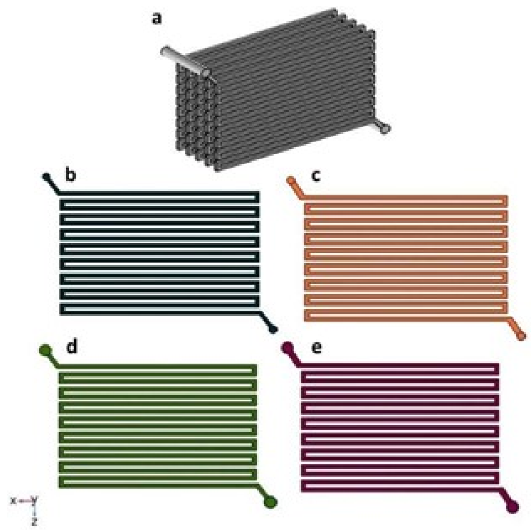

Fig. 1. (a) 5-cell stack, 1(b) case 1, 1(c) case 2, 1(c) case 3 and 1(d) case 4(a) 5-cell stack, 1(b) case 1, 1(c) case 2, 1(c) case 3 and 1(d) case 4

3 RESULTS AND DISCUSSION

The velocity distribution and pressure drop in manifold and distributor is evaluated for detailed discussion.

3.1 Velocity distribution

Fig.2a to 2d, shown the velocity distribution from distributor at inlet manifold to cell 1, cell 3 and cell 5 for all four cases. The maximum velocity is reported in case 1 and minimum is reported in case 4 and whereas, the case 3 is reported moderate velocity. In all cases the intensity of velocity at inlet manifold is reduced when moving from cell 1 to cell 5 due to flow is side-tracked through each cells. Due to smaller manifold diameter and minimum distributor width the velocity in case 1 is high. In case 1 and case 3 the velocity in distributor and channel is almost similar in all the cells. However, this behaviour is not observed in case 2 and case 4 where velocity has notable variation in distributor and at inlet of channels.

Though velocity is low in distributor, a sudden increase at channel entrance creates orifice effect along the channel path which may leads to reactant leakage inside the stack. Though velocity is high in case compared to case the minimum variation in velocity at distributor and flow channels of all the cells reduces the orifice impact and causing the uniform flow As like velocity distribution in distributor shown the velocity variation in inlet and outlet manifolds respectively.

At inlet manifold, The velocity at inlet manifold is similar to velocity in distributor but the outlet manifold shown reduced velocity in all cases. Due to pressure drop in the flow channel the

Table 1: Geometric parameter and fluid properties geometric parameter and fluid properties

Parameter	Value
Channel width (m)	0.002
Channel depth (m)	0.002
Cell length (m)	0.1
Cell width (m)	0.066
Flow rate (m3/s)	5 x 10-5
Hydrogen density (kg/m3)	0.082
Dynamic viscosity (Pa.s)	8.76 x 10-6

velocity in outlet manifold is less

3.2 Pressure drop

The pressure in 4 mm manifold is higher than the pressure in 6 mm manifold. Fig. 5(a) to 5(d) shown the pressure drop in the first cell from case 1 to case 4.

Since, the stack is analysed for flow distribution and no electrochemistry is involved the pressure drop is almost similar in all cells of the stack. The pressure drop indicates that the manifold dimension has greater impact than distributor dimension. Larger the manifold smaller is the pressure drop and vice-versa. In case 1 and case 2 the manifold size is 4 mm but the distributor width is 2 mm and 3 mm. However, the pressure drop is almost same in both cases. Similarly, in case 3 and case 4 the manifold is diameter is 6 mm and the distributor width 2 mm and 3 mm respectively. In these two cases also the pressure drop

4 is similar. Hence, the selection of manifold dimension is more important upon designing the fuel cell stack..

4 Conclusion

- In the present study the effect of manifold and distributor dimension on flow distribution was analysed. Four cases were considered for velocity and pressure drop evaluation. The important findings of the study as provided as follows.
- Smaller manifold diameter and decreased distributor width (case 1 and case 2) leads to high flow channel velocity. which may cause reactant leakage inside the stack.
- Manifold with larger manifold diameter and smaller distributor width (case 3) has equal velocity at both distributor and channel which would resulted in more uniform distribution of

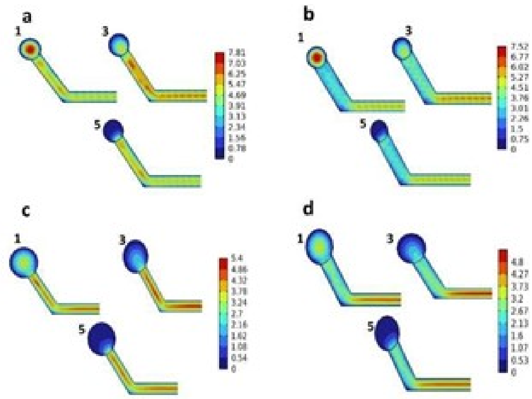

Fig. 2. velocity (m/s) distribution at inlet distributor and channels of cell 1, 3 and 5 from (a). case 1 to (b). case 4velocity (m/s) distribution at inlet distributor and channels of cell 1, 3 and 5 from (a). case 1 to (b). case 4

reactant in the stack.

- Larger manifold and distributor (case 4) had low velocity in the distributor. However, at channel entrance the velocity drastically increases and this leads orifice impact in the channel and subsequently creates leakage.
- Pressure drop in larger manifold is less and in smaller manifold is more. The distributor dimension had no impact on pressure drop.

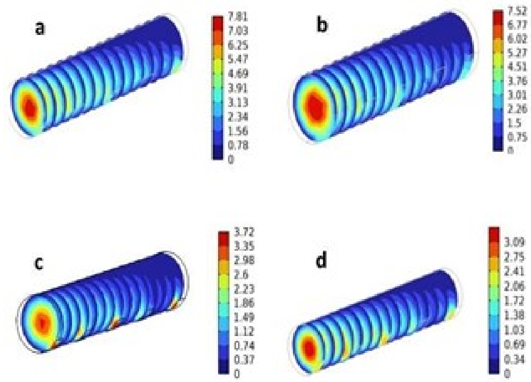

Fig. 3. velocity (m/s) distribution at inlet manifold from case 1 to case 4velocity (m/s) distribution at inlet manifold from case 1 to case 4

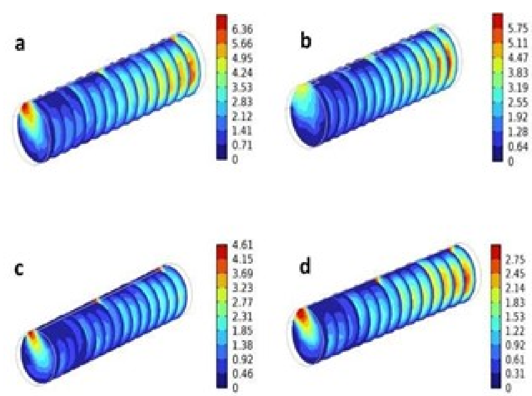

Fig. 4. velocity distribution (m/s) at outlet manifold from (a). case 1 to (d). case 4velocity distribution (m/s) at outlet manifold from (a). case 1 to (d). case 4

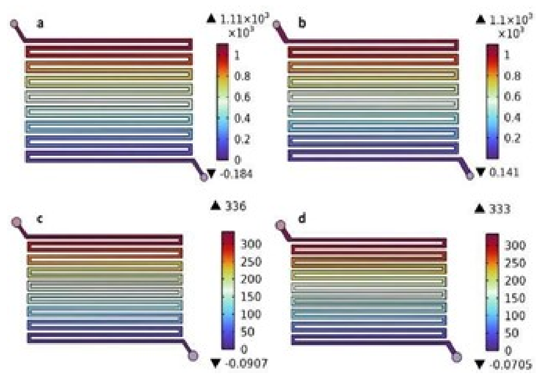

Fig. 5. Pressure drop (Pa) from (a). case 1 to (d). case 4Pressure drop (Pa) from (a). case 1 to (d). case 4

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