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고분자 전해질 연료전지를 위한 연료주입구 설계 및 수치해석

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Design of Inlet Manifold for PEM Fuel Cells and Numerical Analysis

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Key words : U and Z shape manifold(U형 Z형 주입구), Buffer zone(완충지역), Mass flow rate(질량유량)

Abstract : The Performance of a PEMFC stack is strongly dependent on the uniform reactants distribution on MEA. The uniform distribution can be achieved by flow-field pattern and manifold design optimized to satisfy operating conditions. This paper investigates uniform reactants distribution in channels by changing manifold shape and inlet mass flow rate. Typical U and Z shape and modified U and Z shape manifolds with buffer zone were designed. To check the uniform reactants distribution, standard deviation of mass flow rate was compared. The numerical results show that the inlet mass flow rate, inlet shape, and manifolds shape are critical factor for uniform distribution.

Nomenclature

A: area, m^2
u :velocity, m/s
ρ: density, kg/m^3
P : pressure, pascal

subscrip

c : channel
m: manifold
in : inlet
tot: total channel area

1. Introduction

A Fuel cell is an energy converter which changes chemical energy to electrical energy through electrochemical reaction. To perform this role, reactants are supplied from gas tanks and reach in their reaction sites via manifolds and gas channels. For better performance, reactants must be distributed uniformly and uniform distribution on reaction sites is dependent on the channel geometry and its operating conditions from the application requirements(1). For this reason, numerical studies are focused on the flow-filed pattern design to ensure even distribution of reactants on MEA. However, in flow field design studies, uneven distribution of reactants at each cells caused by manifold is overlooked(2). In this paper, numerical simulation for typical U and Z shape 20 cells of 13channel serpentine channels are analyzed and alternative design to attain uniform reactants distribution is suggested.

2. Numerical model

To analyze transport phenomena in manifold and channels, equations are solved in Commercial CFD code Fluent 6.3. with double precision solver. Mesh geometry and Governing equations are written below.

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2.1 Mesh Geometry

Fig. 1. shows the schematic of typical U, Z type. To modify typical manifold, inlet buffer zone with angle about 12° is introduced between manifold and channel inlet. Manifold inlets are classified as A type and B type as in fig. 2. Each stack consists of 20cells in which 13 serpentine channels are engraved. The channel width and depth are both 1mm. The cross-sectional area ratios are $A_m/A_{c,tot}=1.2428:1$ and $A_m/A_{in}=4.42:1$, respectively. Fig. 4. shows the meshed geometry of A type z shape manifold with 20 cells. 13 serpentine channels are engraved in each 20 cell.

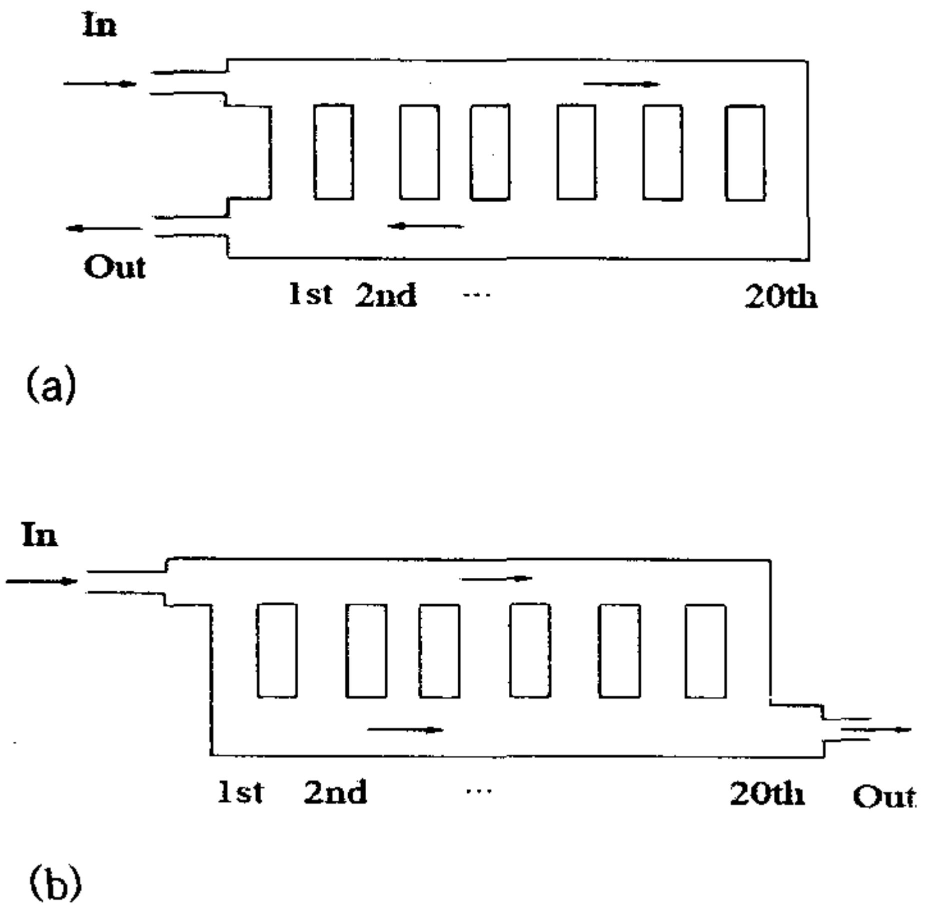

Fig 1. Schematic of manifold shape: (a) U shape manifold and (b) Z shape manifold

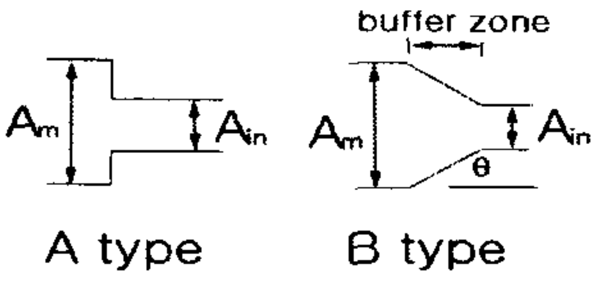

Fig 2. A type manifold inlet shape and B type manifold inlet shape

2.2. Governing equations

The Reynolds Stress Model was used to solve turbulent flow of air about Re 3000~13000. The Reynolds stress model solves individual Reynolds stresses, $\overline{u'_i u'_j}$.[4]

$$\frac{\partial}{\partial x_i}(\rho u_i)=0$$

$$\frac{\partial}{\partial x_i}(\rho u_i u_j)=-\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}-\frac{2}{3}\delta_{ij}\frac{\partial u_l}{\partial x_l}\right)\right]+\frac{\partial}{\partial x_j}\left(-\rho\overline{u'_i u'_j}\right)$$

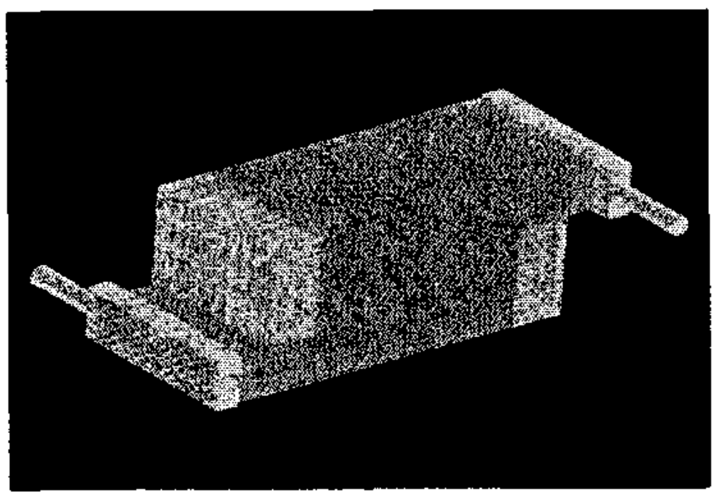

Fig. 3. A type Z shape manifold with 20 cells

3. Result and discussion

Fig. 4. shows the velocity contour of B type U shape manifold. When the air comes into the manifold, the air flows directly to the end wall near 20th cell, and flows back to 3rd, 2nd 1st cell, distributing air into channels. This flow phenomena makes 20th pressure the highest.

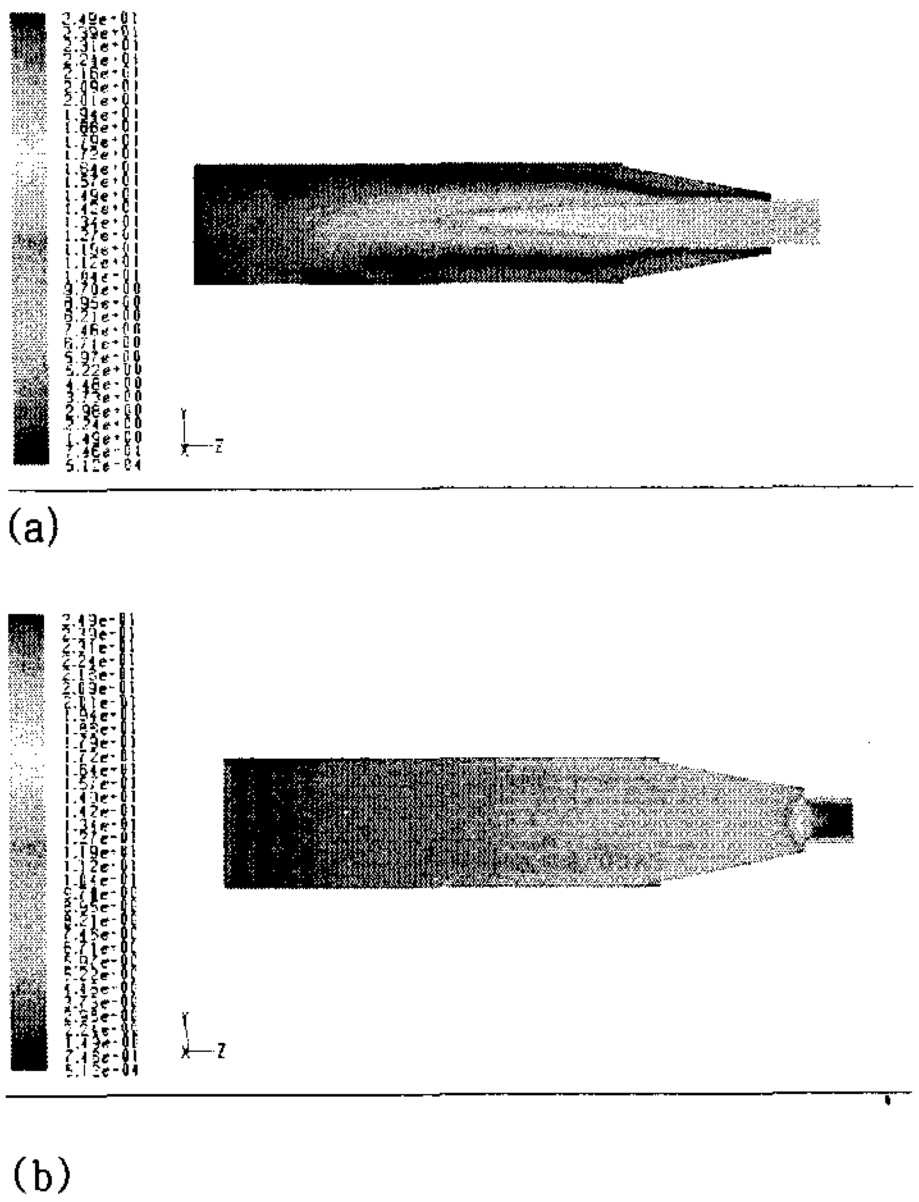

Fig. 4. Velocity contour of B type U shape manifold at 90 LPM (a) inlet manifold and (b) outlet manifold

3.1 Pressure

Fig. 5. shows the inlet pressure at each cell. At 20th cell, pressure is the highest in all cases. At 90 LPM, manifold inlet pressure deviates far from average

pressure. In B type manifold, pressure is the lowest at 1st cell. In A type manifold, pressure is the lowest at the 5th cell. In A type, because of the effect of the wall near first cell, pressure slightly increases. Fig. 6. shows the outlet pressure at each cells. In U shape manifold, outlet located near 1st cell. The pressure is the highest around 20th cell and the lowest around 1st cell. In Z shape manifold, outlet located near 20th cell. The outlet pressure is the highest near 1st cell and the lowest near 20th cell.

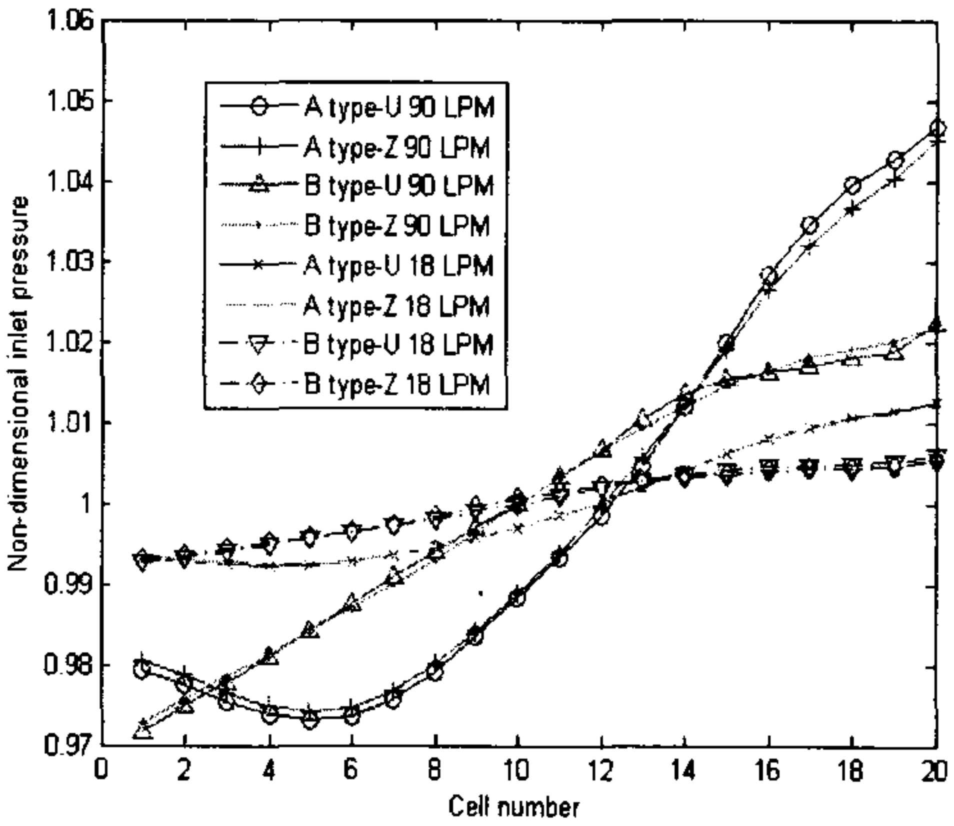

Fig 5. Non-dimensionalized inlet channel pressure of inlet mass flow rate 90 LPM and 18 LPM

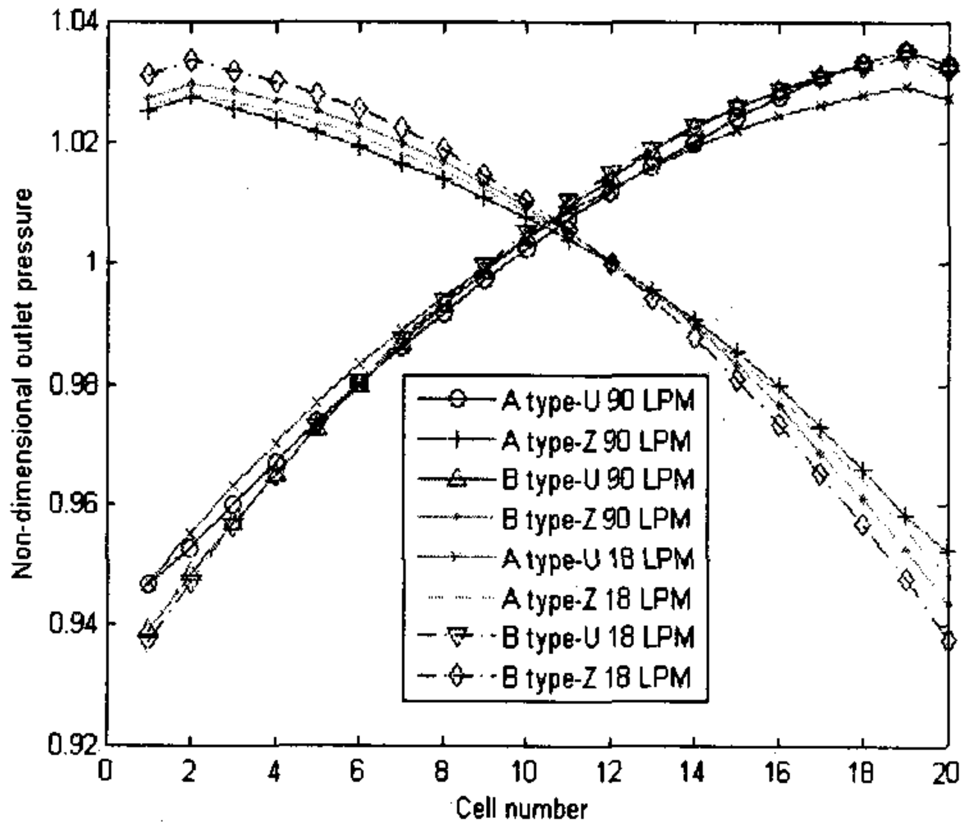

Fig 6. Non-dimensionalized outlet channel pressure of inlet mass flow rate 90 LPM and 18 LPM

3.2 Velocity

Fig. 7. shows the inlet velocity of each cell. Because of influence of pressure, inlet velocity deviates much from average velocity at Z type outlet. In fig. 7. outlet pressure of 1st cell is high at 1st cell in Z type. This makes velocity slow down in first cell, and also next few cells. At 20th cell, outlet pressure of 20th cell is low and inlet velocity increases. This makes maxim deviation of velocity in A type Z shape 90 LPM case. In B type manifold, because of buffer zone, the change of velocity is not abrupt. This helps uniform velocity distribution. At high LPM, inlet velocity increases and deteriorates uniform distribution.

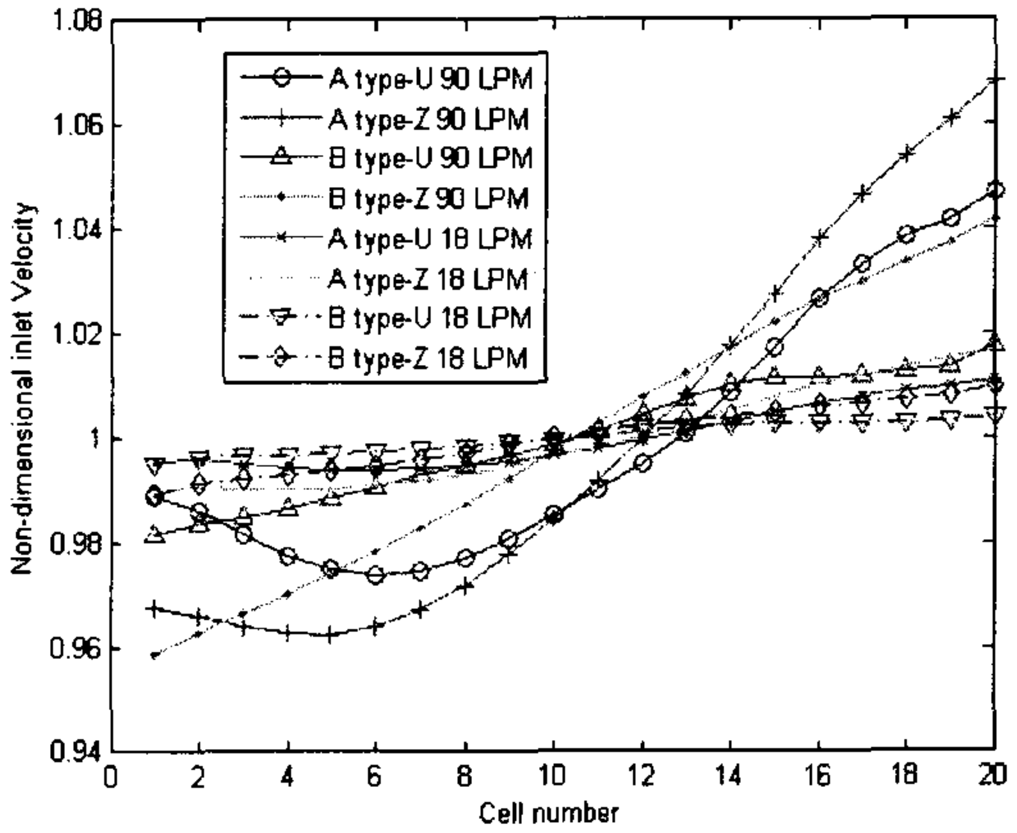

Fig 7. Non-dimensionalized inlet channel velocity of inlet mass flow rate 90 LPM and 18 LPM

3.3 Mass flow rate

Fig. 8. shows mass flow rate at each cell inlet. Since ρ , A_c are constants, Uniformity of mass flow rate is depend on uniformity of velocity. To verify uniformity, mass flow rate was monitored at total 260 channels in 20 cells of 13 channels. Based on this information, standard deviation was calculated in table 1. Standard deviation of B type U shape at 18 LPM was the minimum and the standard deviation of A type Z shape at 90 LPM was the maximum. The maximum deviation for B type U shape at 18 LPM is 1% whereas the maximum deviation for A type Z shape at 90 LPM is 10%. This suggest that low inlet velocity with B type and U shape case will give the most uniform mass flow distribution.

	18 LPM	90 LPM
A type U shape	1.1020e-8	1.8488e-7
A type Z shape	1.5333e-8	2.6947e-7
B type U shape	7.9773e-9	9.4781e-8
B type Z shape	1.1379e-8	1.9607e-7

Table1. Standard deviation of mass flow rate

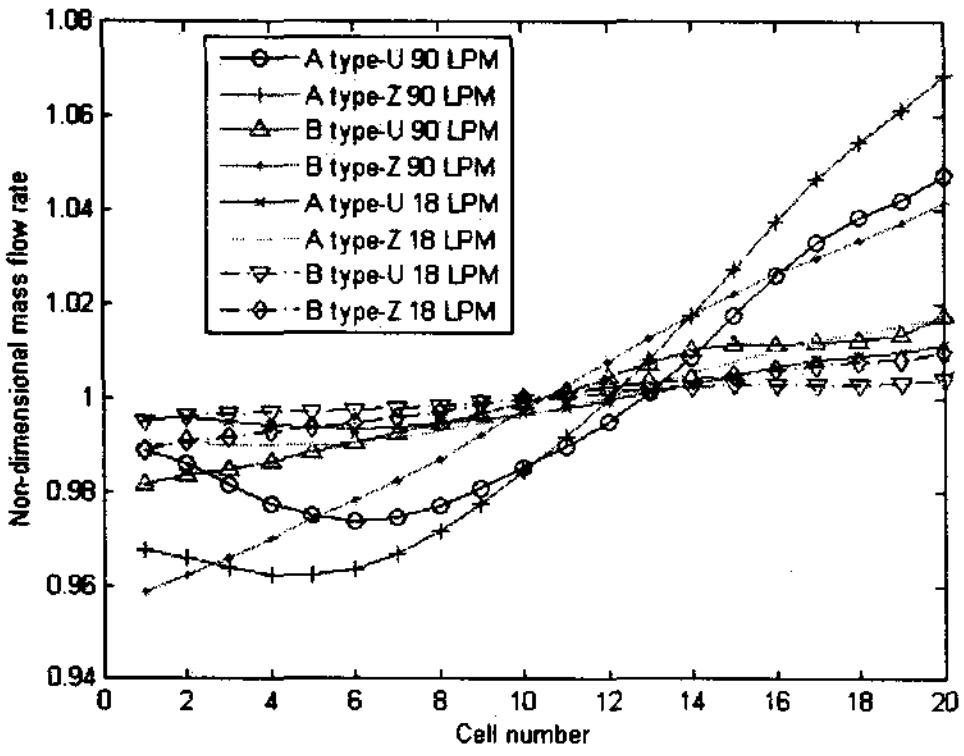

Fig 8. Non-dimensionalized outlet channel pressure of inlet mass flow rate 90 LPM and 18 LPM

4. Conclusion

Numerical analysis of 20 cells stacks with U and Z shape manifold is performed. From the simulation results, it can be concluded that the uniform reactants distribution can be achieved with U shape manifold. Also, changing manifold inlet size to lower inlet velocity and placing buffer zone at inlet of manifold will bring beneficial effect on uniform reactants distribution. To further elaborate the design of fuel cell manifold, simulation with electrochemical reaction which causes density change in each channel should be performed simultaneously.

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