ISSN 2321-807X
Volume 13 Number9
Journal of Advances in chemistry

IMPACT OF PRESSURE ON THE PERFORMANCE OF PROTON EXCHANGE MEMBRANE FUEL CELL

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ABSTRACT

The performance of the Proton Exchange Membrane (PEM) fuel cell is measured with respect to the power output of the PEM fuel cell. The power output of PEM fuel cell is not only depending on temperature but also depending on the operating pressure. In this paper, the power output of the PEM fuel cell is analyzed by varying the operating pressure. The PEM fuel cell with serpentine flow field was modeled using Solidworks software and analyzed using ANSYS software. From the analysis of three different pressures on the PEM fuel cell, the optimum operating pressure was found.The peak power density occurs at the pressure of 2 bar and operating temperature of 323 K. The best cell potential was also found in this paper

Keywords

PEM, pressure, peak, performance, power

INTRODUCTION

In current scenario the major problem faced by every country is the environmental pollution. To reduce the pollution, we need an alternative source rather than fossil fuels. To produce a clean environment, the world need alternative resources which has zero emission, reduce the pollution, fossil fuel depletion and enhancement of fuel supply. Fuel cell is concerned as the best alternative resource in recent years owing to their advantages.

The proton exchange membrane (PEM) fuel cell is a device which is used to convert chemical into electrical energy. At the anode, hydrogen is fed to the cell and a reaction takes place at the catalyst layer as below.

$$H_2 \longrightarrow 2H^+ + 2e^-$$

The protons travel from side to side the polymeric membrane and react with the oxygen and the electrons at the cathode catalyst layer as below.

$$\frac{1}{2} O_2 + 2H^+ + 2e^- \longrightarrow H_2O$$

Therefore, the overall reaction taking place in the PEM fuel cell is:

$$H_2 + \frac{1}{2} O_2 \longrightarrow H_2O + \text{Electricity} + \text{Heat}$$

The PEM fuel cell has many advantages. It is relatively operated at low temperature upto100^{0}C, offer quick start up times. It requires only hydrogen and oxygen to operate. In this PEM fuel cell less chance of pollution as compare to other source of energy because output will be water. It is eco-friendly power generating system. It is suitable for both portable and stationary applications due to high energy density and low operating temperature range. Ibrahim Dincer [1] studied Assessments of the sustainability of processes and systems, and efforts to improve sustainability, should be based in part upon thermodynamic principles, and especially the insights revealed through exergy analysis. Renewable energy utilization in hydrogen production can provide a potential solution to current environmental problems.

Effects of design and operating parameters

Hong Liu et al. [2] compared various flow field design from among all serpentine is the best design. P. Karthikeyan et al. [3] optimized operating condition and design parameter by using Taguchi method will improve the performance of PEM fuel cell. A.P. Manso et al. [4] work, the authors present a thorough review on the influence of geometric parameters of the flow field on the performance of a PEM fuel cell. Tanmay Basak et al. [5] analyzed numerically the naturalconvection within porous trapezoidal enclosures for various inclination angles. The various parameters Influencing the performance of PEM fuel cell was analyzed using ANSYS [6].

The performance of the PEM fuel cell is majorly depending on the channel length and number of channel. Feser et al. [7] concluded that, in a single serpentine flow field geometry, the percentage of flow passing through the GDL is based on the material and geometric parameters of bipolar plates. The convection was slightly depending upon the gas diffusion layer geometry. When the length of the flow channel was increased, the convective flow was also greater than before. The performance of the square type of PEM fuel cell has more benefits than the rectangular cross sectional area of the cell. Shimpalee et al. [8] concluded that the performance is majorly depending upon the flow path and the length of the flow path. The performance of the PEM fuel cell overall is depending on the fluid flow channel. The 3-channel flow, 6-channel

DOI : 10.24297/jac.v13i9.5739
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flow and 13-channel flow were analyzed. When 6-channel flow field is compared with 13-channel flow there is a slight performance increment that is considered by the uniform current density distribution and lower water flooding effect.

Hontan E et al.[9] analyzed the different flow channel cross section shapes such as semi-circular, trapezoidal and triangular. The rectangular cross section shape has more advantage than the both of the channels. Wang Xiao-Donget al. [10] analyzed the tapered flow channel at cathode with the active area of 81 mm2 and compared to the straight channels. The cell power output of the optimized flow channel had the increment of 11.9 over the straight flow channels. Lin et al. [11] investigated the taper flow channel designs and the diverging channel designs. Both diverging and taper channel designs improved the performance of the fuel cell because of the local oxygen transport rate and the further advantage of the diverging channel was to minimize the fluid leakage at outlet. Erasmo Mancusi et al. [12] analyzed a three dimentional mathematical model of the fuel cell flow channel at different temperatures with different taper angles. The tapering effect has increased the power density, due to the increase in the gas velocity. Also the effect of hydrophobicity of the gas diffusion layer was studied that plays in liquid water formation. When the contact angle decreases, the film formation is increased. A novel cathode flow field with porous carbon inserts along the rib of the cathode flow field was studies by karthikeyan et al. [13-14]. The tubular plates in PEM fuel cell was studied by Sierra et al. [15]. Due to the reduction in flow path angle and the twist of the flow channels, there is a easy removal of water from the gas diffusion layer, thereby improves performance can be obtained. Preeyaphat Wawdee et al. [16] studied the new flow field with up and down slanted flow channels of PEM fuel cell with bigger active area for performance improvement. The different landing width and the channel width of 0.5x0.5, 1x1, 1.5x1.5 and 2x2 mm were studied by Muthukumar et al. [17]. They found that the PEM fuel cell with landing to channel width of 0.5 x 0.5 mm can give the better performance. The performance of different passes of serpentine flow field was analyzed by Muthukumar et al. [18] using three dimensional PEM fuel cell.

MODEL CREATION OF PEM FUEL CELL

The 3D mathematical model of serpentine channeled and rectangular outlet flow channel PEM fuel cell is created as shown in Fig.1, Fig.2 & Fig.3. It consists of the membrane, flow channels on anode and cathode, catalyst layers and gas diffusion layers in both anode and cathode. The Fig.1 displays the 3D model of PEM fuel cell with serpentine flow channel design with curved bend. By using the Volume of fluid method, the model is created. The dimensions of the flow plate is 80 mm x 80 mm. The inlet and outlet diameter are 2 mm. The flow channel width and height are taken as 2 mm. The rib width is also taken as 2 mm. The active area of PEM fuel cell is 25 cm^2. The parameters of serpentine channel PEM fuel cell is listed in Table 1.

Table 1. Dimensions of PEM fuel cell model

S.NO.	PARAMETER	VALUE
1	Channel length	50 mm
2	Outlet channel height	2 mm
3	Inlet channel height	2 mm
4	Thickness of catalyst layer	0.08 mm
5	Thickness of GDL	0.3 mm
6	Thickness of membrane	0.127 mm
7	Active area	25 cm^2

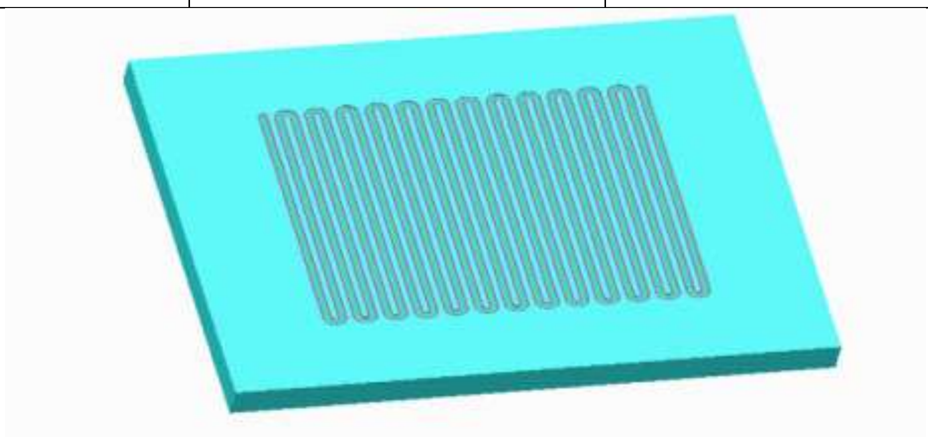

Fig. 1: Model of serpentine channel flow field of PEM fuel cell

ISSN **2321-807X**
Volume 13 Number9
Journal of Advances in chemistry

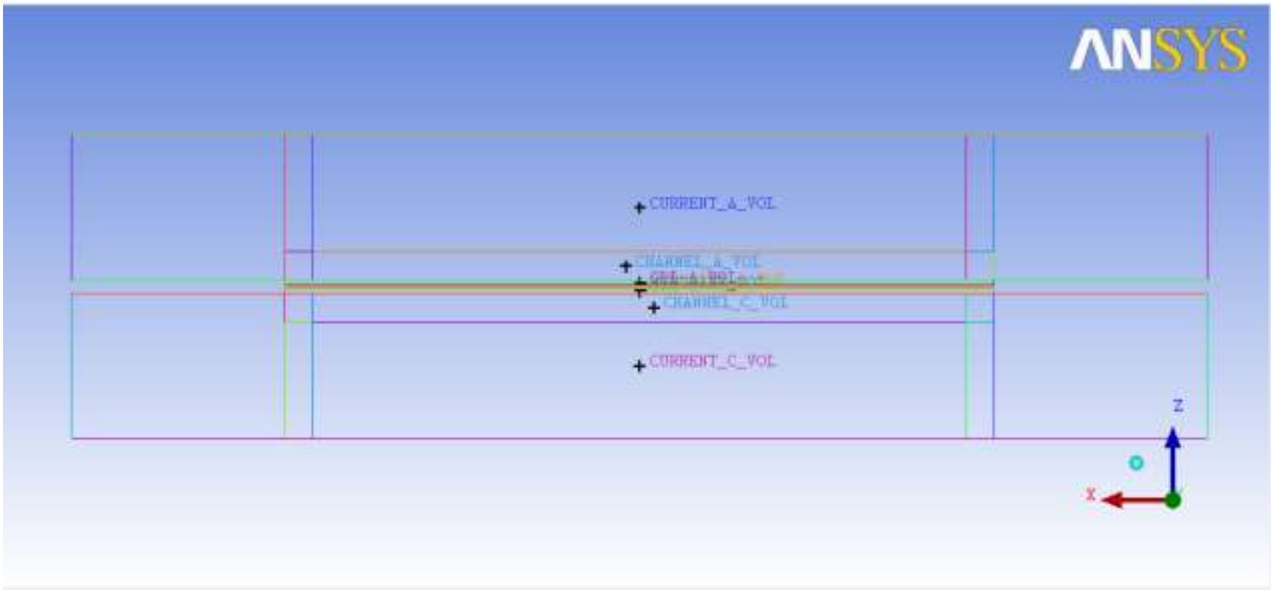

Fig. 2: Side view of serpentine channel flow field

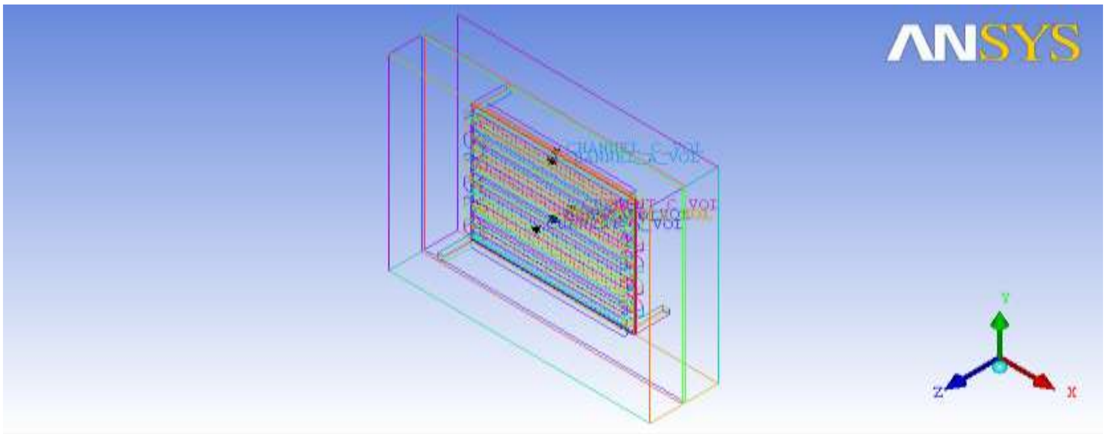

Fig. 3: Isometric view of serpentine channel flow field PEM fuel cell

SOLVER

A control volume approach based on commercial solver FLUENT 14.5 was used to solve the various governing equations. Before that, according to the dimension, the 3D model of PEM fuel cell was made using SOLID WORKS 14.0 and meshed using ICEM CFD 14.5 as shown in Fig.4. Later, the analysis was done with three different pressure (1 bar, 1.5 bar, 2 bar) and voltage (0.25 V-0.85 V) at constant temperature of 323 K (50^oC) using Ansys and checked.

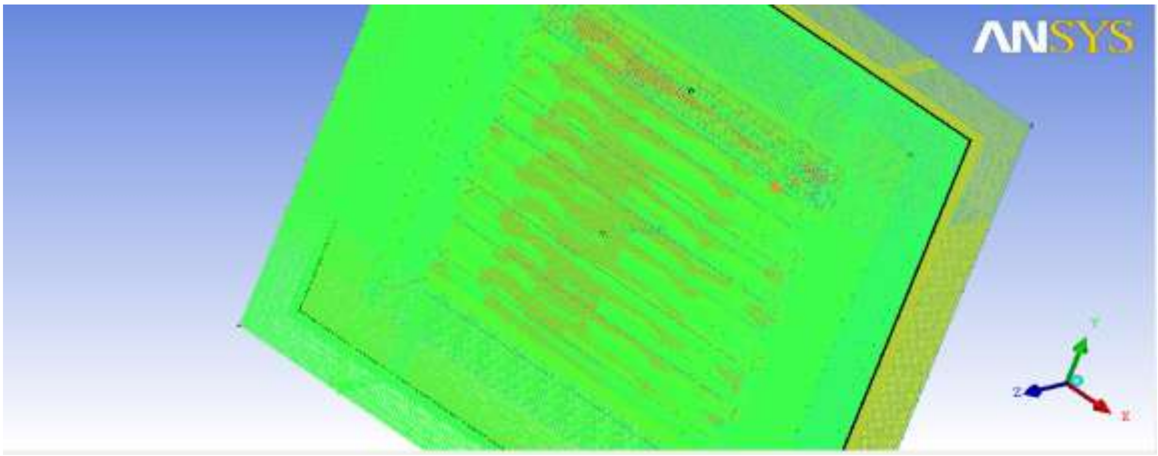

Fig. 4: Meshing of model

RESULT AND DISCUSSION

The influence of various operating pressure with different cell voltages were analyzed for serpentine U bend flow channel. From the entire three results, 0.55 V with pressure of 2 bar gives high performance as compared to others. For 1 bar with 0.55 V, the current density was found to be 1.206385 A/cm^2 and the power density was found to be 0.66351175 W/cm^2 . For 1.5 bar with 0.55 V, the current density was found to be 1.206648 A/cm^2 and the power density was found to be 0.6636564 W/cm^2 . For 2 bar with 0.55 V, the current density was found to be 1.207008 A/cm^2 and the power density was found to be 0.6638544 W/cm^2 . These values are tabulated in Table 2. While comparing the performance of PEM fuel cell with three different pressures and at constant temperature, it was found that the pressure 2 bar is the optimum pressure at the cell potential of 0.55 V. The Fig.5, Fig.6 and Fig.7 show the numerical results at 1 bar, 1.5 bar and 2 bar respectively.

Table 2. Camparison of results

S.No.	Pressure (bar)	Voltage (V)	Current density (A/cm^2)	Power density (W/cm^2)
1	1	0.55	1.206385	0.66351175
2	1.5	0.55	1.206648	0.6636564
3	2	0.55	1.207008	0.6638544

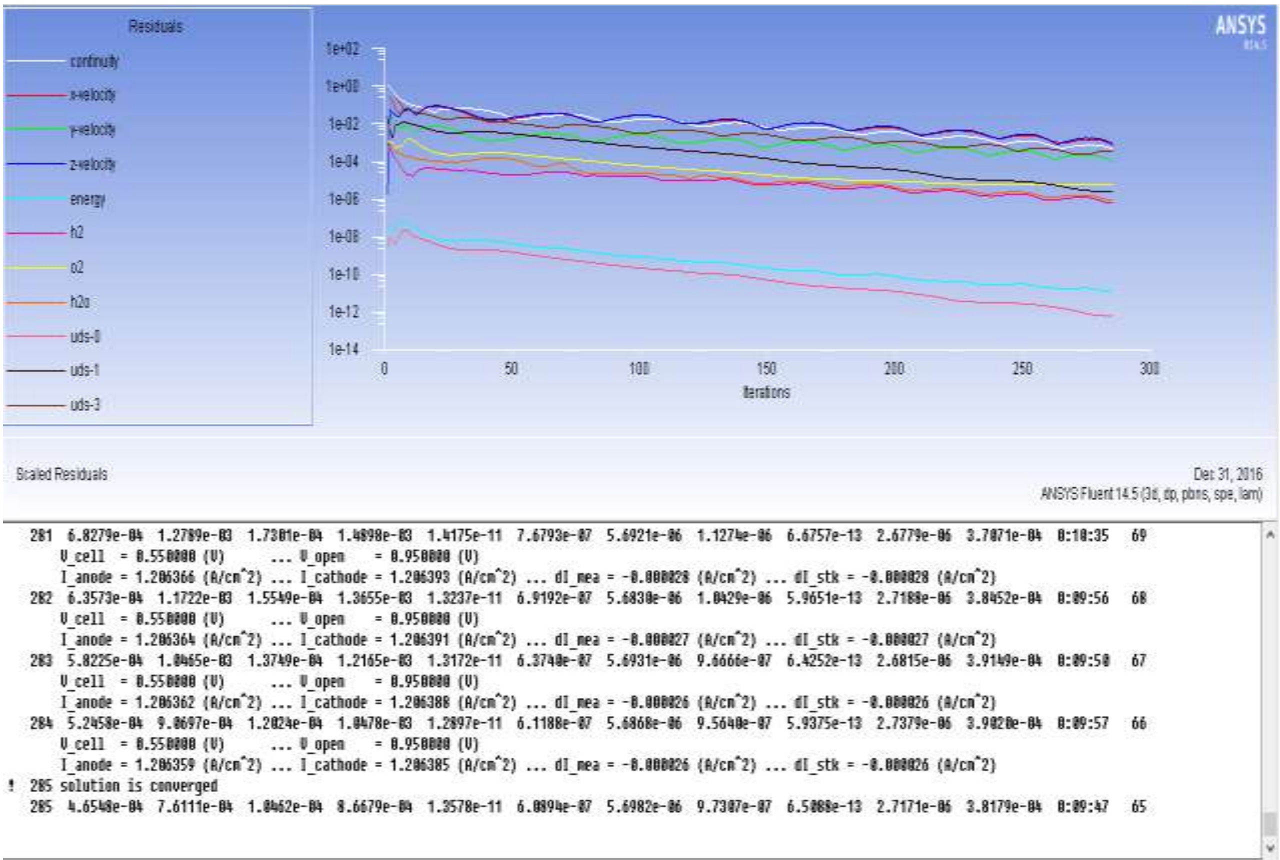

Fig. 5: Result for pressure of 1 bar at 0.55V

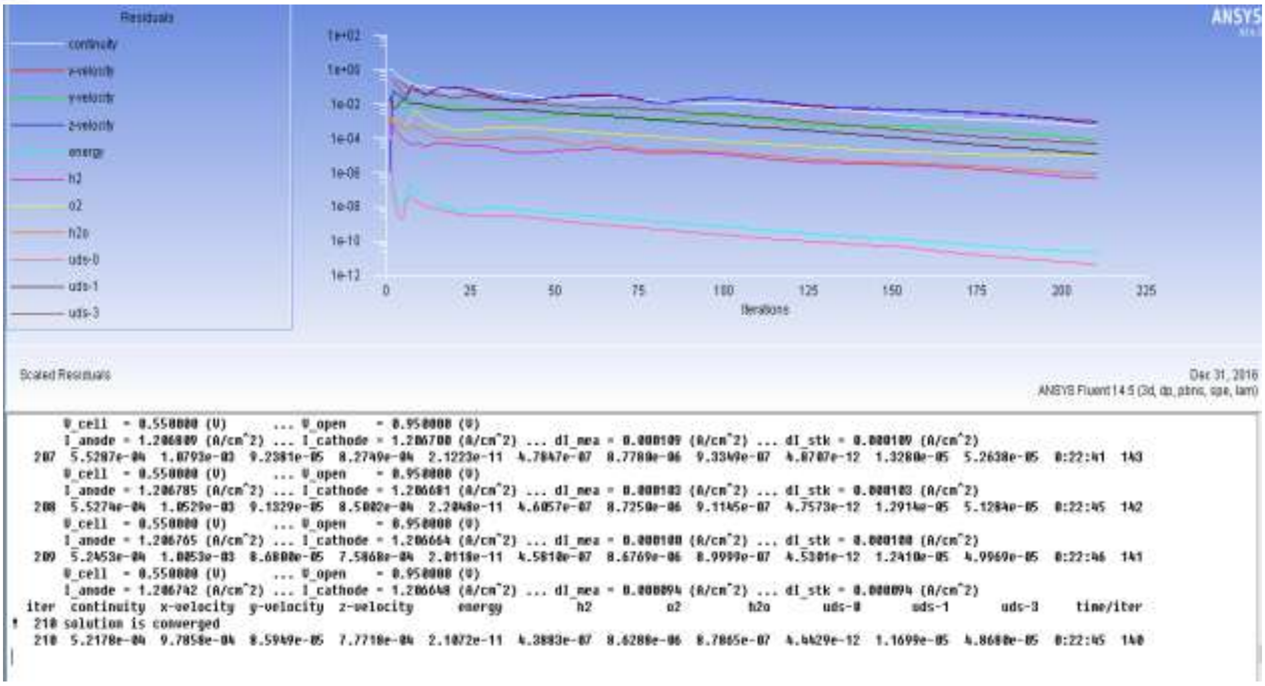

Fig. 6: Result for pressure of 1.5 bar at 0.55V

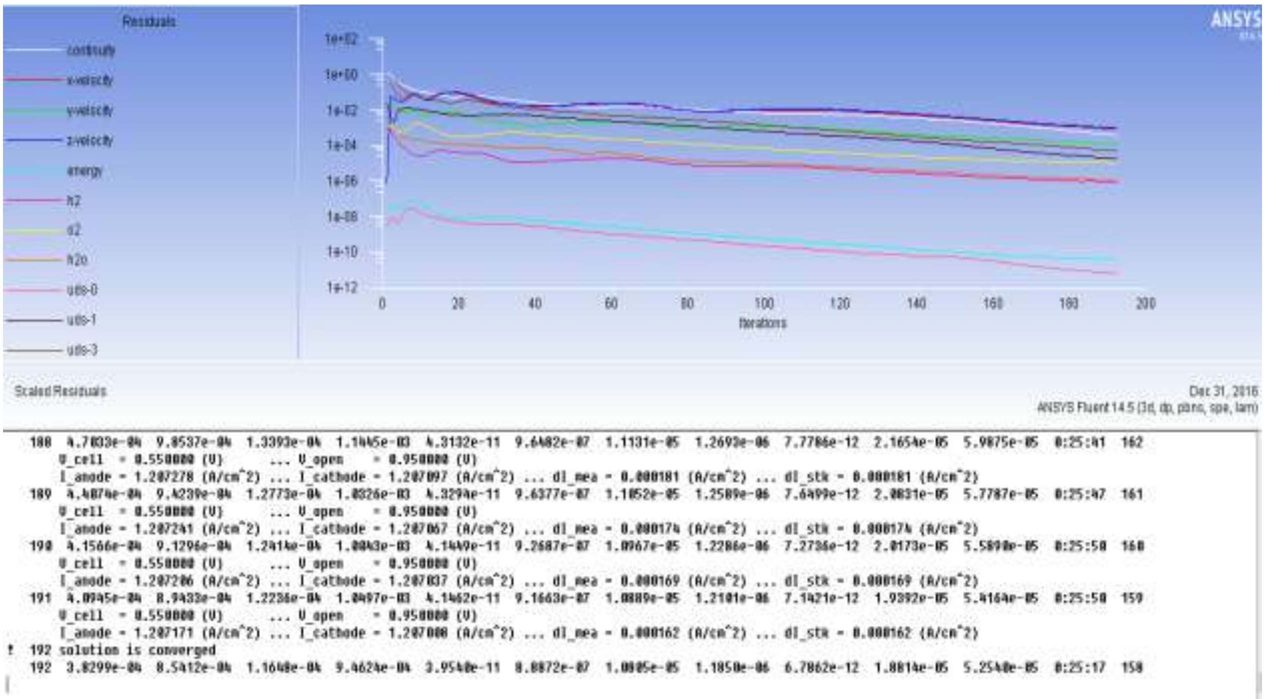

Fig. 7: Result for pressure of 2 bar at 0.55V

CONCLUSION

The power density and performance of PEM fuel cell are influenened by many parameters like temperature, pressure, mass flow rate, humidity of input gases etc. In this paper, the effect of pressure on the performance of PEM fuel cell was analyzed numerically. The PEM fuel cell with active area of 25 cm^2 and serpentine type flow field with U bend was modeled using SolidWorks 14.0; and meshing and analysis were done using Ansys 14.5 software packages. The PEM fuel cell with three different pressures of 1 bar, 1.5 bar and 2 bar with constant temperature of 323 K is analyzed. From the numerical results, it is found that 2 bar pressure at 323 K is giving the best power output and performance of PEM fuel cell potential at 0.55 V cell potential.

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DOI : 10.24297/jac.v13i9.5739