PERFORMANCE ANALYSIS OF A BIPOLAR PLATE IN A FUEL CELL USING COMPUTER FLUID DYNAMICS STUDIES

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ABSTRACT
Over the past ten years, proton exchange membrane (PEM) fuel cells have gained popularity as a potential energy source. PEM fuel cells are a high efficiency, environmentally friendly power source that are not constrained by Carnot efficiency. Due to its characteristics of zero emissions, high power density, rapid start-up, and low operating temperature, they are seen as one of the attractive options to be utilized for electric cars.
In this project work, a fuel cell uses that a low cost bipolar plate material with a high fuel cell performance are important for the establishment of PEM fuel cells into the competitive market world are taken in consideration. The analysis is carried out for the selected materials like Aluminium, Copper and Stainless steel on considering the design and operational parametric conditions of the PEM fuel cell. The aluminium bipolar plate exhibits improved uniformity in the dispersion of hydrogen, oxygen, and water vapour, which will improve the ionic conductivity in the membrane. After analysing the data, we found that the aluminium bipolar plate material had the best temperature distribution in the fuel cell and the lowest pressure loss when compared to the copper and stainless steel materials. Therefore, due to its light weight and reasonably low price of material, aluminium serpentine bipolar plate material may be thought of as the ideal bipolar plate material, especially for portable applications.
Keywords—Fuel Cell, Geometry Generation, Methodology, Analysis

1. Introduction

A fuel cell is an electrochemical device that converts the energy produced by a chemical reaction into electrical energy. Fuel cells are in need of a continual input of fuel and an oxidizing agent (generally oxygen) in order to encourage the reactions that will produce the electrical energy. Accordingly, fuel cells can constantly produce electricity up to the contribution of fuel and oxygen is cut away. Despite being created in 1838, fuel cells didn't come into widespread use until the 1960s. A century later, NASA employed them to run satellites and spacecraft. Today, many establishments, including businesses, residences, and other buildings, use fuel cells as their main or backup power supply. A cathode, an anode, and an electrolyte are the components of electrochemical cells, which are comparable to fuel cells. The electrolyte in these cells allows the protons to travel. In the cells depicted below, fuels such as hydrogen (H_2), carbon dioxide (CO_2), methane (CH_4), propane (C_3H_8), methanol (CH_3OH), and others are utilized to generate electrical energy. The fuel cell is constantly fed, while the products are constantly eliminated. Fuel cells provide significant advantages over traditional combustion-based technologies that are now employed in many power plants and cars. Fuel cells have better efficiency than combustion engines and can transfer the chemical energy in fuel straight to electrical energy with efficiencies reaching 60%. When compared to combustion engines, fuel cells emit little or no pollution [1]. Because there are no carbon dioxide emissions from hydrogen fuel cells, they solve significant climate issues. There are also no air contaminants at the place of operation that cause pollution or health issues. Because fuel cells have few moving parts, they operate

quietly. An overview of the key aspects that influence the stability of solid oxide fuel cell components, their implications on cell performance, and the sources of cell deterioration has been included.
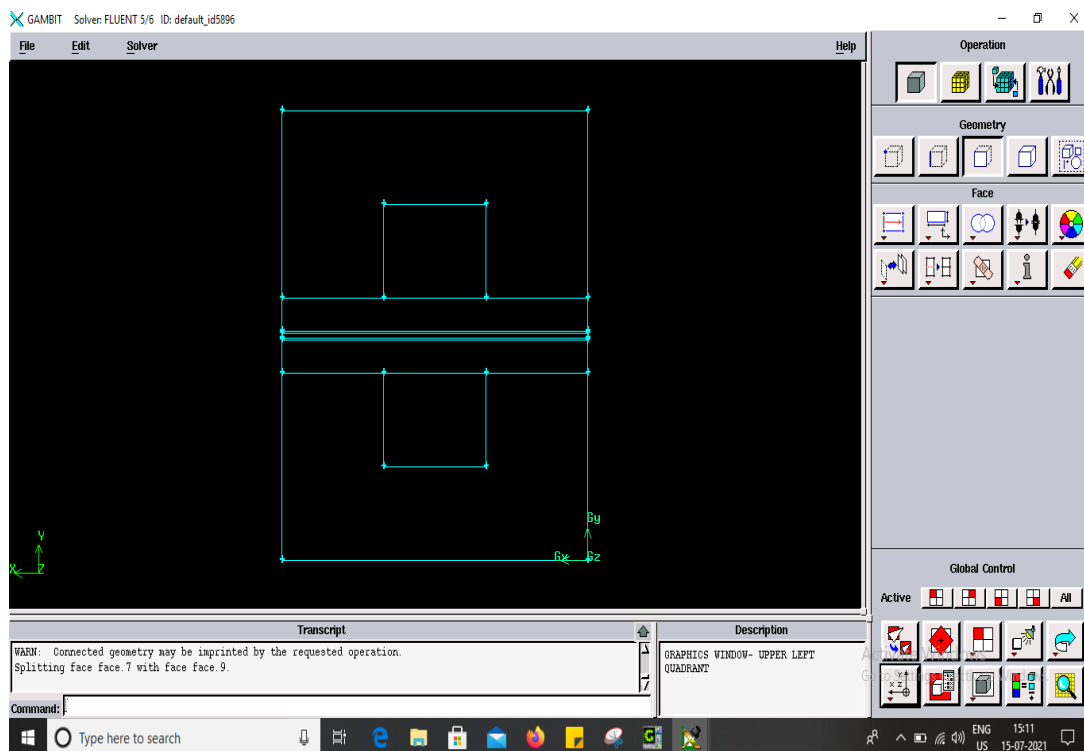
2. Geometry Generation
2.1   Geometric Properties

SL.NO	PARAMETERS	VALUE	UNIT
1	Current collector (anode)	45	mm
2	Current collector (cathode)	45	mm
3	Active area	25	cm²
4	Membrane thickness	0.6	mm
5	Catalyst layer thickness	0.08	mm

Table. 1. Geometric Properties

2.2   Description of PEM Fuel cell & Bipolar Plate

Fig. 1. PEM Fuel cell zones

2.3   Geometry Creation
1. Create a rectangular face primitive in the xy plane.
- Operation−→Geometry −→Face −→Create Real Rectangular Face
- Enter 2.4 for Width and 1.2 for Height.

- Select +X +Y for Direction
- Click Apply and close the Create Real Rectangular Face panel

2. Create another face by sweeping the uppermost edge by 0.21 units in the   y-direction.

- Operation−→Geometry −→Face −→Sweep Edges

3. Create another face by sweeping the uppermost edge by 0.012 units in the y-direction
4. Create another face by sweeping the uppermost edge by 0.036 units in the y-direction.
5. Create another face by sweeping the uppermost edge by 0.012 units in the y-direction.
6. Create another face by sweeping the uppermost edge by 0.21 units in the y-direction
7. Create another face by sweeping the uppermost edge by 1.2 units in the y-direction
8. Create a rectangular face with dimensions (x,y) = (0.8,0.6). Use +x+y for thedirection
9. Move the newly created face using a vector of (0.8, 0.6, 0)
10. Copy the face by 1.08 units in the y-direction. 11. Split the lowermost face withthe face you just created.

- Operation−→Geometry −→Face −→Split Face

2.4   Mesh Generation

   1. Mesh the edges as shown in Figure 2.
   Operation−→Mesh −→Edge −→Mesh Edges
   2. Mesh the nine faces using the Quad Sub map scheme.
   Operation−→Mesh −→Face −→Mesh Faces
   3. Create an edge by sweeping any one of the vertices by 125 units in the positive zdirection.
    Operation−→Geometry −→Edge −→Sweep Vertices

(a)   Select Vector for Path and click the Define button.
(b)   Enable Magnitude and enter 125.
(c)Select Positive for Z from the Direction list.
(d)   Click Apply in the Vector Definition form.
(e)   Click Apply and close the Sweep Vertices form.

4. Mesh the newly created edge using a double-sided graded edge mesh that consistsof 60 elements.
       (a) Enable Double sided.
      (b) Enter 1.1 for Ratio 1 and Ratio 2.
      (c) Click Apply and close the Mesh Edges form.

5. Create volumes by sweeping the nine faces along the newly created edge.
             Operation−→Geometry −→Volume −→Sweep Faces

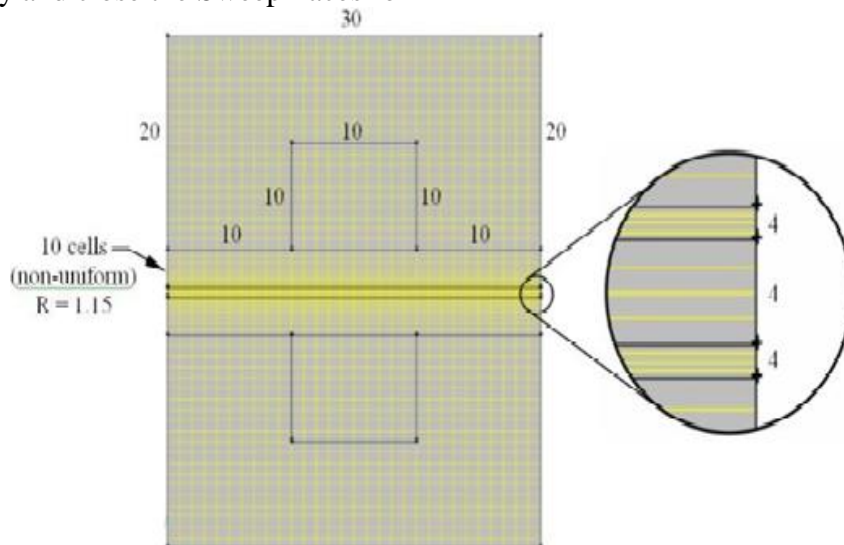(a) Enable With Mesh.
(b) Click Apply and close the Sweep Faces form
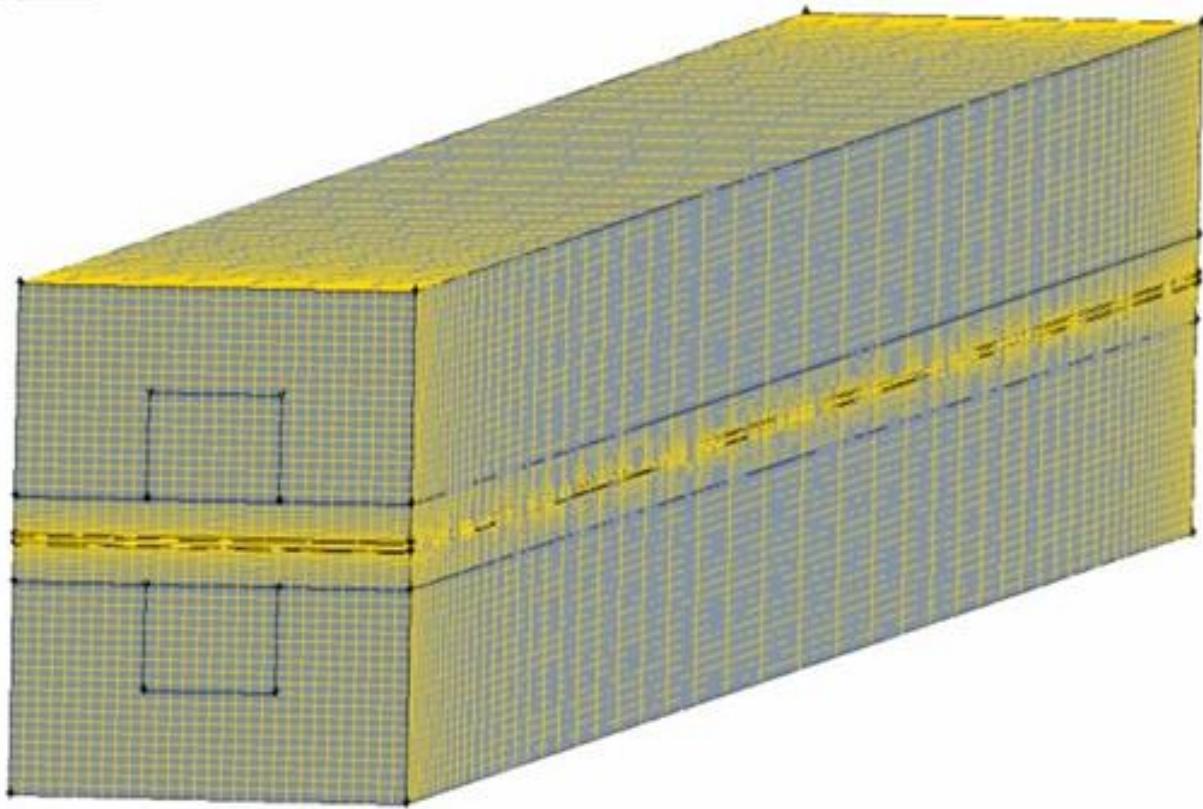

Fig. 2. Edge and Face mesh

Fig. 3. Volume Mesh

3. Methodology
3.1   Generic Steps To Solving Problem in Fluent
Like fixing any hassle analytically, you want to define (1) your answer domain, the bodily version, (3) boundary situations and (4) the bodily properties. You then remedy the hassle and gift the results. In numerical methods, the principle distinction is a further step referred to as mesh generation. This is the step that divides the complicated version into small factors that grow to be solvable in an in any other case too complicated situation. Below describes the tactics in terminology barely extra attune to the software. The format of ANSYS Fluent workbench used for CFD analysis.

Build Geometry: Construct a two or three dimensional representation of the object to be modelled and tested using the work plane coordinates system within ANSYS.

Define Material Properties: Now that the part exists, define a library of the necessary materials that compose the object (or project) being modelled. This includes thermal and mechanical properties.

Generate Mesh: At this point ANSYS understands the makeup of the part. Now define how the Modelled system should be broken down into finite pieces. The geometry of meshing in ANSYS fluent.

Define Boundary Conditions: Once the system is fully designed, the last task is to burden the system with constraints, such as physical loadings or boundary conditions. Figure 6. 3 shows the setup initialization in Ansys workbench for defining the boundary conditions.

Obtain Solution: This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved. This can be achieved by using the Ansys Fluent software.

SL.N0	SOLUTION METHODS	INPUTS
1	Scheme	Simple
2	Pressure	Second order

3	Initialization	Standard initialization
4	Gas outlet	Pressure outlet
5	Assumption	The model external surfacesare assumed as a wall
6	Operational temperature for each bipolar plate	298K & 323K
7	Number of Iteration	500
8	Turbulence Model	K - ε
9	Multi-grid cycle function	Altered to F-cycle forsimulation stabilization

Table. 2. Boundary Conditions for Simulation

SL.NO	Parameters	Value	Unit
1	Operating temperature	298/323	K
2	Operating pressure	1.5/2	Bar
3	Relative humidity at anode side	100	%
4	Relative humidity at cathode side	100	%
5	Open circuit voltage	0.7	V

Table. 3. Parameters used for Simulation

4. Results and Discussion

Fluent software program application includes the broad, physical modelling abilities needed to model go with the flow, turbulence, warmth transfer and reactions for commercial enterprise applications. These range from air go with the flow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood go with the flow to semiconductor manufacturing and from clean room format to wastewater treatment plants. Fluent spans an expansive range, which includes specific models, with abilities to model in-cylinder combustion, aero-acoustics, turbo-system and multiphase systems. Fluent moreover offers quite scalable, high-ordinary overall performance computing (HPC) to help treatment complex, large-model computational fluid dynamics (CFD) simulations short and cost-effectively.

CFD simulations of fuel line mobileular have been accomplished for all four extraordinary substances. Industrial scaled geometries are exported into FLUENT 6.3 and actual plant jogging conditions are taken as input to validate the results.

3.1 Effects of Operating Temperature Variation

The running temperature does play a important position in enhancing gasoline mobileular overall performance. In PEM gasoline mobileular, growing the running temperature is beneficial in improving electrochemical response, ionic shipping rate, and the elimination of water from the gasoline mobileular. Similarly, the gasoline mobileular temperature can have an effect on membrane existence span and overall performance due to the fact if the membrane receives dry and live like that for a protracted time, this will bring about rupturing of the membrane. When gazing the effect of the running temperature at the mobileular overall performance, different parameters have been stored regular even as best the temperature became varied.

The contours for temperature distribution with inside the channels for aluminium, copper and metallic substances are proven in Figures four–9, respectively, for each anode and cathode facet at temperatures of 298, 323, and 338 K at 0.7 V. The temperature distribution will increase with growth in temperature. It may be located on the interface among the catalyst layer and membrane in the anode region of each material that the temperature distribution is slightly one of a kind throughout every flow field channels and having temperature versions among 1 and six K. However, it became observed that the best temperature is on the cathode facet for diverse substances temperature distribution with inside the channel because of electrochemical response.
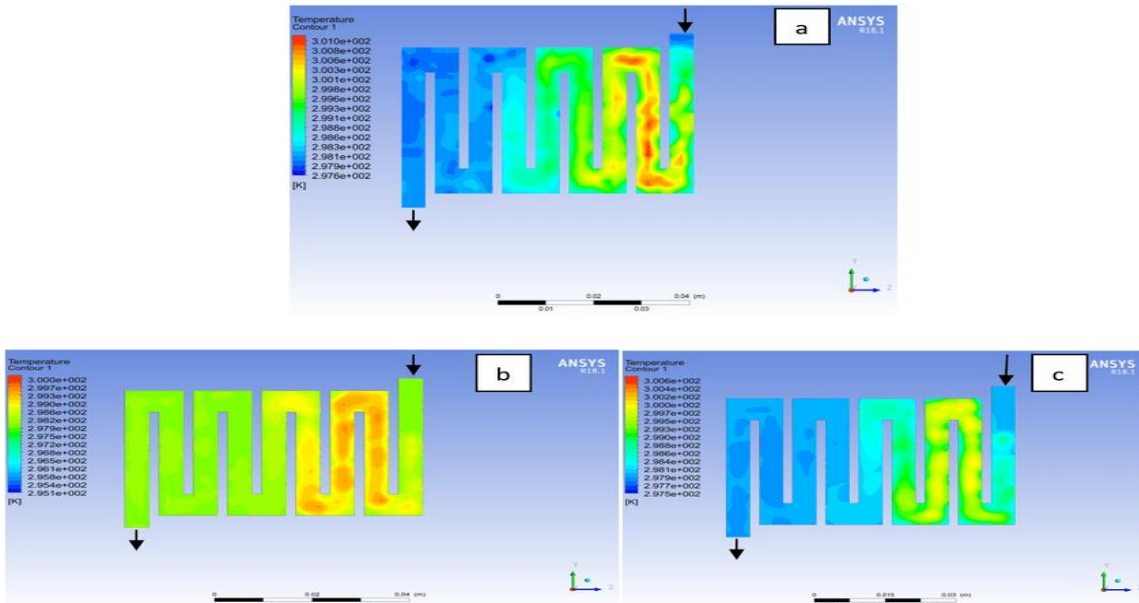
Fig. 4. Temperature distribution at the cathode region for each material at 298K: (a) Aluminum, (b) Copper, (c) Steel.
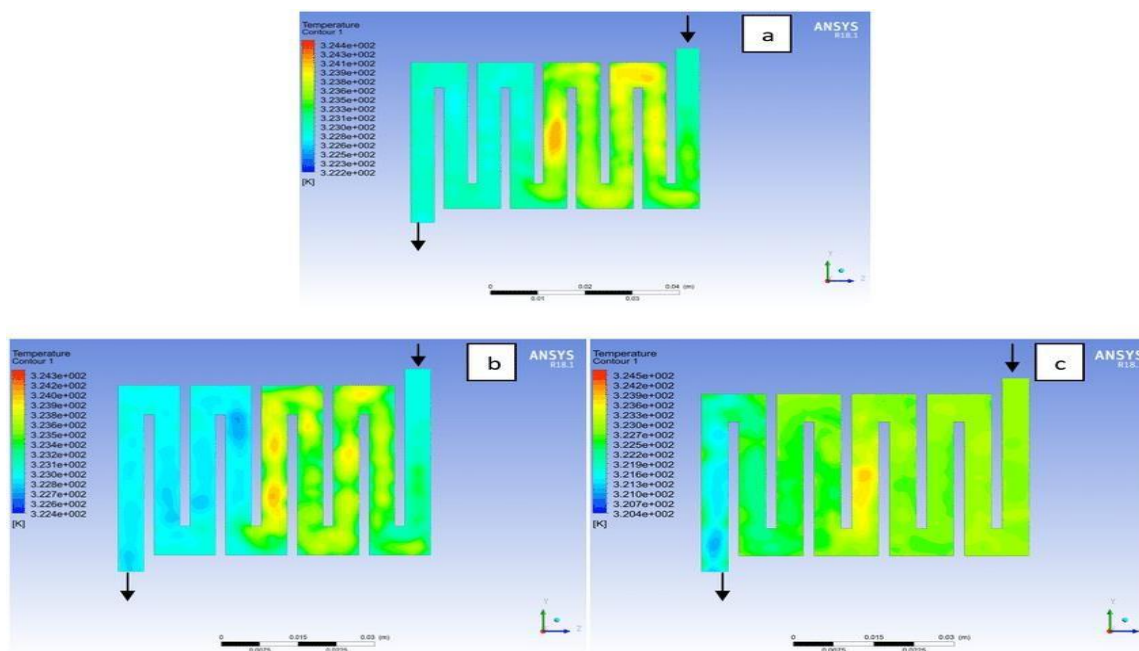

Fig. 5. Temperature distribution at the cathode region for each material at 323K: (a) Aluminum, (b) Copper, (c) Steel.

3.2 Effects of Operating Pressure Variation

Fuel cell operation could be at ambient pressure or pressurized state. Increase in pressure improves cell performance. The reactant in- flow pressure is always higher than the outflow pressure as a result of pressure drop within the flow field channels. Among the significant parameter that needs to be taken into account when designing a PEM fuel cell is pressure drop. The flow field channel is often the place where the pressure drop does take place and it does affect the electrochemical reaction of the fuel cell pressure drop is more at the inlet flow and gradually decreases along the outlet flow channel for all the bipolar plate materials. It is observed that Al material has the least significant pressure drop at a different pressure range of the fuel cell than Cu and SS bipolar plate material. Besides bending and frictional losses, the adsorption of the reactants on the floor of the bipolar plate substances have contributed to the results.
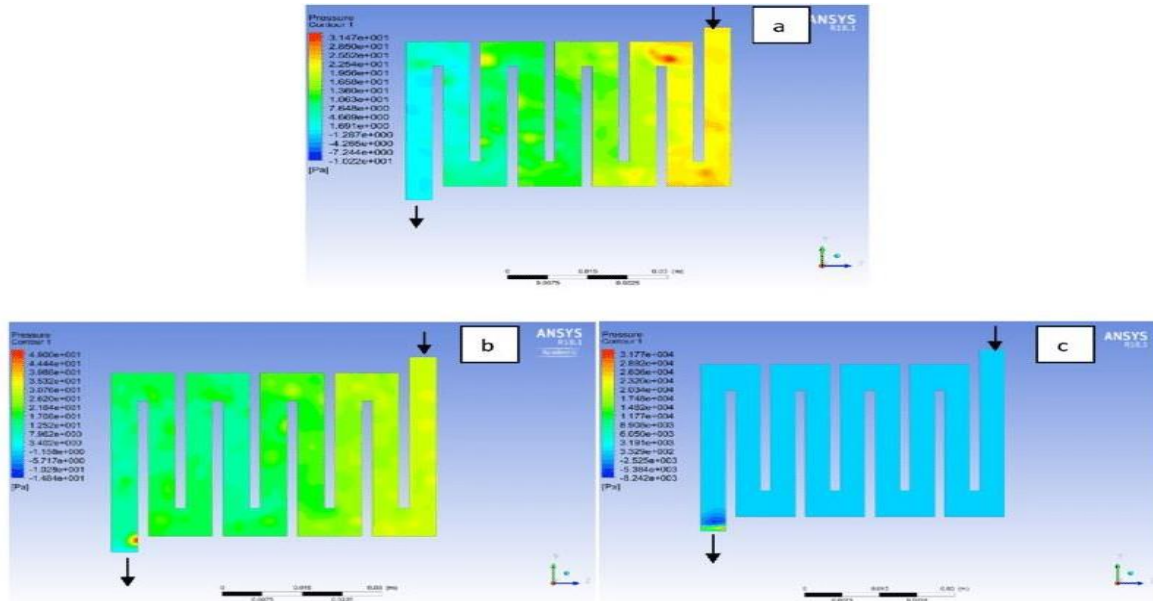
Fig. 6. Pressure distribution at the cathode region for each material with temperature 323 K at 2.0bar: (a) Aluminum, (b) Copper, (c) Steel
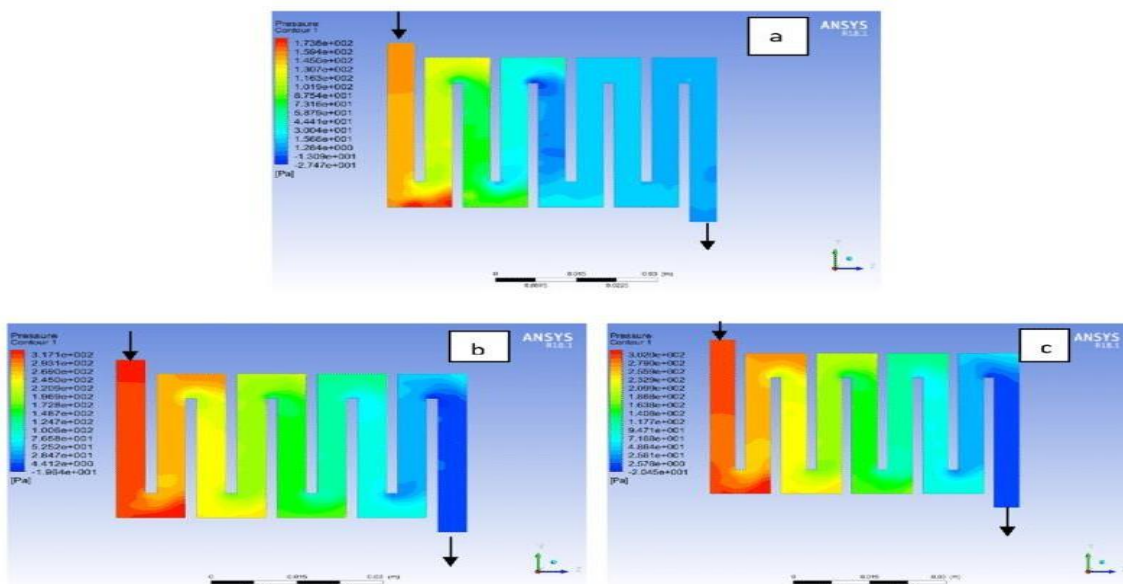

Fig. 7. Pressure distribution at the cathode region for each material with temperature323 K at 2.5 bar: (a) Aluminium, (b) Copper, (c) Steel

CONCLUSION

In this project work the analysis for the geometry of PEM fuel cell was carried out using ANSYS CFD. The simulations have been carried out for the selected bipolar plate materials like Aluminium, Copper and Stainless steel. The geometry of the PEM fuel cell and bipolar plate was described earlier in the previous chapter with the objective of reducing the cost of the bipolar plate that is being used and to increase the temperature variation and reduce the pressure variation.

Al bipolar plate cloth temperature distribution with inside the gasoline mobileular changed into the great and it has the bottom stress drop than Cu and SS cloth .Al bipolar plate indicates a higher uniformity & growth the ionic conductivity with inside the membrane. The simulation outcomes displaying that Al serpentine bipolar plate has the great usual PEM gasoline mobileular overall performance due to the fact Hydrogen molecules is extra strong on Al floor than Cu and SS surfaces.

Al serpentine bipolar plate material can be considered to be used as the best bipolar plate material, especially for portable applications due to it light weight and reasonable cheap price of material

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