Design and Analysis of Flow Field Geometry Designs of Proton Exchange Membrane (Pem) Fuel Cell

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Abstract: - To create an Evergreen environment and to generate power in automobiles, the different energy sources are necessary. In order to control the emission and fossil fuel Enervations Proton exchange membrane (PEM) fuel cells has been used. It has some main advantages like zero emission, easy implementation, long life and lower operating temperature. The performance of PEM fuel cell can be improved by varying the operating parameters and geometrical parameters in flow channel. Its primary function is to supply the reactant gases to gas diffusion electrodes.

The main purpose of this project is to lift the various cross sections like Spherical, Quadrilateral and Triangle of PEM fuel cell in order to increasing the velocity and acceleration of the fluid in flow channel. Due to the effects of this variation, the current density may be increased. The development of these design techniques are carried out in the platform of Creo and analyzed with CFD. The results are validated.

Keywords:-Fossil fuel, Enervations, reactant gases, Spherical, Quadrilateral, acceleration, current density

1. INTRODUCTION

1.1 OVERVIEW OF FUEL CELLS

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction of positively charged hydrogen ions with oxygen or another oxidizing agent. Fuel cells are different from batteries in that they require a continuous source of fuel and oxygen or air to sustain the chemical reaction, whereas in a battery the chemicals present in the battery react with each other to generate an electromotive force (EMF). Fuel cells can produce electricity continuously for as long as these inputs are supplied.

There are many types of fuel cells, but they all consist of an anode, a cathode, and an electrolyte that allows positively charged hydrogen ions (or protons) to move between the two sides of the fuel cell. The anode and cathode contain catalysts that cause the fuel to undergo oxidation reactions that generate positively charged hydrogen ions and electrons. The hydrogen ions are drawn through the electrolyte after the reaction. At the same time, electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. At the cathode, hydrogen ions, electrons, and oxygen react to form water. As the main difference among fuel cell types is the electrolyte, fuel cells are classified by the type of electrolyte they use and by the difference in startup time ranging from 1 second for proton exchange membrane fuel cells (PEM fuel cells, or PEMFC) to 10 minutes for solid oxide fuel cells (SOFC). Individual fuel cells produce relatively small electrical potentials to create sufficient voltage to meet an application's requirements. In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions. The energy efficiency of a fuel cell is generally between 40–60%, or up to 85% efficient in cogeneration if waste heat is captured for use.

Now days the world is concerned about the alternative sources to produce a cleaner environment by overcoming the emissions due to pollution and depletion of fossil fuels. One of the best alternative sources is a fuel cell. Due to the advantages and reliability of the fuel cell, it considered as the best alternative source. Depending upon the electrolyte used in the fuel cell, it has to be classified as follows, 1. Proton exchange membrane fuel cell, 2.Solid oxide fuel cell, 3.Phosphoric acid fuel cell, 4.Molten carbonate fuel cell. Due to the benefit of zero emission, the PEM fuel cell has to be chased as best alternative instead of energy sources.

Fuel cells are the one, which converts the chemical reaction in the fuel cell into electrical energy. PEM fuel cell consists of three segments like anode, membrane, and cathode. Anode is made up of platinum powder, cathode is made up of Nickel, and Nano material based catalyst membrane that is used to separate the anode and cathode side. Bipolar plates, catalyst, membrane and the hardware are the secondary components of PEM fuel cell. Hydrogen diffuses to the anode catalyst that changed the protons
and electrons. The protons are conducted from side to side the membrane and arrive at the cathode side. Due to the electrical insulating on the membrane, the electrons are forced to travel in external circuits on the cathode catalyst; oxygen reacts with electrons and produce water as a by product.

Despite their success in space programs, fuel cell systems were limited to space missions and other special applications, where high cost could be tolerated. It was not until the late 1980s and early 1990s that fuel cells became a real option for wider application base. Several pivotal innovations, such as low platinum catalyst loading and thin film electrodes, drove the cost of fuel cells down, making development of PEMFC systems more realistic.

1.2 TYPES OF FUEL CELL

1.3.1. Phosphoric Acid Fuel Cell (PAFC)

Phosphoric acid fuel cells (PAFC) were first designed and introduced in 1961 by G. V. Elmore and H. A. Tanner. In these cells phosphoric acid is used as a non-conductive electrolyte to pass positive hydrogen ions from the anode to the cathode. These cells commonly work in temperatures of 150 to 200 degrees Celsius. This high temperature will cause heat and energy loss if the heat is not removed and used properly. This heat can be used to produce steam for air conditioning systems or any other thermal energy consuming system. Using this heat in cogeneration can enhance the efficiency of phosphoric acid fuel cells from 40–50% to about 80%. Phosphoric acid, the electrolyte used in PAFCs, is a non-conductive liquid acid which forces electrons to travel from anode to cathode through an external electrical circuit.

Since the hydrogen ion production rate on the anode is small, platinum is used as catalyst to increase this ionization rate. A key disadvantage of these cells is the use of an acidic electrolyte. This increases the corrosion or oxidation of components exposed to phosphoric acid.

The chemical reactions for the SOFC system can be expressed as follows:

Anode Reaction: $2\text{H}_2 + 2\text{O}^2^- \rightarrow 2\text{H}_2\text{O} + 4\text{e}^-$

Cathode Reaction: $\text{O}_2 + 4\text{e}^- \rightarrow 2\text{O}^2-$

Overall Cell Reaction: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

1.3.2. Solid Oxide Fuel Cells (SOFCs)

Solid oxide fuel cells (SOFCs) use a solid material, most commonly a ceramic material called yttrium-stabilized zirconium (YSZ), as the electrolyte. Because SOFCs are made entirely of solid materials, they are not limited to the flat plane configuration of other types of fuel cells and are often designed as rolled tubes. They require high operating temperatures (800–1000 °C) and can be run on a variety of fuels including natural gas.

SOFCs are unique since in those, negatively charged oxygen ions travel from the cathode (positive side of the fuel cell) to the anode (negative side of the fuel cell) instead of positively charged hydrogen ions travelling from the anode to the cathode, as is the case in all other types of fuel cells. Oxygen gas is fed through the cathode, where it absorbs electrons to create oxygen ions. The oxygen ions then travel through the electrolyte to react with hydrogen gas at the anode. The reaction at the anode produces electricity and water as by-products. Carbon dioxide may also be a by-product depending on the fuel, but the carbon emissions from an SOFC system are less than those from a fossil fuel combustion plant.

1.3.3. Hydrogen-Oxygen Fuel Cell

The Hydrogen-Oxygen Fuel Cell was designed and first demonstrated publicly by Bacon in the year 1959. It was used as a primary source of electrical energy in the Apollo space program. The cell consists of two porous carbon electrodes impregnated with a suitable catalyst such as Pt, Ag, Co, etc.

The space between the two electrodes is filled with a concentrated solution of KOH or NaOH which serves as an electrolyte. $2\text{H}_2$ gas and $\text{O}_2$ gas are bubbled into the electrolyte through the porous carbon electrodes. Thus the overall reaction involves the combination of hydrogen gas and oxygen gas to form water.

The cell runs continuously until the reactant's supply is exhausted. This type of cell operates efficiently in the temperature range 343 K to 413 K and provides a potential of about 0.9 V.

1.3.4. Molten Carbonate Fuel Cell (MCFC)

Molten carbonate fuel cells (MCFCs) require a high operating temperature, 650 °C (1200 °F), similar to SOFCs. MCFCs use lithium potassium carbonate salt as an electrolyte, and this salt liquefies at high temperatures, allowing for the movement of charge within the cell – in this case, negative carbonate ions.

Like SOFCs, MCFCs are capable of converting fossil fuel to a hydrogen-rich gas in the anode, eliminating the need to produce hydrogen externally. The reforming process creates CO₂ emissions.

The chemical reactions for an MCFC system can be expressed as follows:

Anode Reaction: $\text{CO}_2^{2-} + \text{H}_2 \rightarrow \text{H}_2\text{O} + \text{CO}_2 + 2\text{e}^-$

Cathode Reaction: $\text{CO}_2 + \frac{1}{2}\text{O}_2 + 2\text{e}^- \rightarrow \text{CO}_3^{2-}$

Overall Cell Reaction: $\text{H}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{H}_2\text{O}$
2. METHODOLOGY

PROBLEM IDENTIFICATION

From the entire study of the literature survey, it was found that the performance of the PEM fuel cell is majorly depending on the flow channel cross section and the flow field.

The flow channel cross section and flow field used for uniform gas distribution and forcing on the catalyst surface also contributes to enhance the chemical reaction.

Both the Physical properties and Gas flow channel construction play crucial roles for affecting the water transport through the Gas diffusion layer in Proton Exchange Membrane fuel cell. So we can change the cross sections of the flow channel the flow properties also change.

3. PROTON EXCHANGE MEMBRANE FUEL CELLS

3.1 INTRODUCTION

In the archetypical hydrogen–oxide proton exchange membrane fuel cell design, a proton-conducting polymer membrane (typically nafion) contains the electrolyte solution that separates the anode and cathode sides. This was called a “solid polymer electrolyte fuel cell” (SPEFC) in the early 1970s, before the proton exchange mechanism was well understood. (Notice that the synonyms “polymer electrolyte membrane” and “proton exchange mechanism” result in the same acronym.)

On the anode side, hydrogen diffuses to the anode catalyst where it later dissociates into protons and electrons. These protons often react with oxidants causing them to become what are commonly referred to as multi-facilitated proton membranes.

The protons are conducted through the membrane to the cathode, but the electrons are forced to travel in an external circuit (supplying power) because the membrane is electrically insulating. On the cathode catalyst, oxygen molecules react with the electrons (which have travelled through the external circuit) and protons to form water.

In addition to this pure hydrogen type, there are hydrocarbon fuels for fuel cells, including diesel, methanol (see: direct-methanol fuel cells and indirect methanol fuel cells) and chemical hydrides. The waste products with these types of fuel are carbon dioxide and water. When hydrogen is used, the CO₂ is released when methane from natural gas is combined with steam, in a process called steam methane reforming, to produce the hydrogen.
3.2 MAJOR COMPONENTS OF PEMFC

The different components of a PEMFC are,
1. Bipolar plates
2. Electrodes
3. Catalyst
4. Membrane, and
5. Current collectors

Fig: 3.2 Components of PEMFC

3.3 WORKING PRINCIPLE

The proton exchange membrane fuel cell (PEMFC) uses a water-based, acidic polymer membrane as its electrolyte, with platinum-based electrodes. PEMFC cells operate at relatively low temperatures (below 100 degrees Celsius) and can tailor electrical output to meet dynamic power requirements. Due to the relatively low temperatures and the use of precious metal-based electrodes, these cells must operate on pure hydrogen.

PEMFC cells are currently the leading technology for light duty vehicles and materials handling vehicles, and to a lesser extent for stationary and other applications. The PEMFC fuel cell is also sometimes called a polymer electrolyte membrane fuel cell (also PEMFC).

Fig: 3.3 Working Setup

Hydrogen fuel is processed at the anode where electrons are separated from protons on the surface of a platinum-based catalyst. The protons pass through the membrane to the cathode side of the cell while the electrons travel in an external circuit, generating the electrical output of the cell.

On the cathode side, another precious metal electrode combines the protons and electrons with oxygen to produce water, which is expelled as the only waste product; oxygen can be provided in a purified form, or extracted at the electrode directly from the air.

A variant of the PEMFC, which operates at elevated temperatures, is known as the high temperature PEMFC (HT PEMFC). By changing the electrolyte from being water-based to a mineral acid-based system, HT PEMFCs can operate up to 200 degrees Celsius.

This overcomes some of the current limitations with regard to fuel purity with HT PEMFCs able to process reformate containing small quantities of Carbon Monoxide (CO). The balance of plant can also be simplified through elimination of the humidifier.

3.4 EXISTING FLOW CHANNELS

Fig: 3.4 Flow Channels and Its Arrangement

The anode and cathode graphite plates, with flow channels fabricated, are assembled together with membrane electrode assembly (MEA). Two plastic endplates are used to sandwich the fuel cell to maintain good electrical contact between all components.

Since the electrical contact resistant between the graphite plates and the gas diffusion layers depends on pressure applied on the contacting surfaces, all the assembly of the fuel cells should have
the same compression to ensure that study and comparison of the fuel cell performance for other factors is based on the same contact resistance. A torque meter was used to indicate the same torque on the bolts when assembling a fuel cell.

3.4.1. Fuel Cell Assembly

The anode and cathode graphite plates, with flow channels fabricated, are assembled together with membrane electrode assembly (MEA). Two plastic endplates are used to sandwich the fuel cell to maintain good electrical contact between all components.

Since the electrical contact resistant between the graphite plates and the gas diffusion layers depends on pressure applied on the contacting surfaces, all the assembly of the fuel cells should have the same torque.

Fig: 3.5 Flow Cell Assembly

A torque meter was used to indicate the same torque on the bolts when assembling a fuel cell.

3.4.2. Flow Field

The flow field geometric configuration has little influence on the overall PEM fuel cell performance at high operation potentials. On the contrary, at low operation potentials, it significantly affected. The flow fields that offer a lower pressure drop generally shows lower performance.

Although the elimination of condense water in the cathode is improved, the energy required to drive the gas increases, reducing the overall performance of the PEMFC. In serpentine type flow fields, longer straight channel segments between channel bends and narrower channels enhance convection. In addition, contrary to what can be expected, an increase in the active area of the MEA results in a decrease of current density.

Fig: 3.6 Flow Field Arrangement

3.4.3. Cross Section Shape

Rectangular is still the most commonly used cross-section channel design for bipolar plates. Other cross-section shapes may show improvements in some specific aspects of the fuel cell operation.

Fig: 3.7. Circle Section

Fig: 3.8. Square section
3.4.4. Channel and Rib Width

Generally, narrower gas flow channels produce better results. The optimal rib width largely depends on PEM fuel cell operation conditions and the type of oxidizing agent used. Thus, fuel cells operating at high potentials, display better performance with wider ribs. On the other hand, in fuel cells operating with air as oxidizing agent, the rib width must be smaller than that for fuel cells operating with pure oxygen.

3.4.5. Channel Depth

In serpentine gas flow channels, reductions in flow channel height, especially at the cathode outlet, improves the mass transfer towards the diffusing layers, promotes water elimination, enhance the electrochemical reaction and increase the fuel efficiency, allowing better results in fuel cell performance. Variations in the channel height only show appreciable effect when operating at low potentials, increasing the current densities. The main disadvantage is that the pressure drop increases, which reduces the overall system efficiency.

3.5 CONFIGURATION OF PEM FUEL CELL GAS FLOW FIELDS

Researchers have developed four general types of flow fields in the past. As shown in above Fig. they are the ones with serpentine flow channels, parallel flow channels, interdigitated flow fields, and flow field with pin-type current collectors.

Table 3.1 Geometrical Parameters for Serpentine Flow Channel

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>DIMENSION</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gas channel length</td>
<td>20.00</td>
</tr>
<tr>
<td>2</td>
<td>Gas channel width</td>
<td>20.00</td>
</tr>
<tr>
<td>3</td>
<td>Diffusion layer height</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>Catalyst layer height</td>
<td>0.08</td>
</tr>
<tr>
<td>5</td>
<td>Membrane height</td>
<td>0.027</td>
</tr>
<tr>
<td>6</td>
<td>Current collector width</td>
<td>20.00</td>
</tr>
<tr>
<td>7</td>
<td>Current collector height</td>
<td>3.00</td>
</tr>
</tbody>
</table>

Flow field and flow channel are also important parameters to improve the performance of PEM fuel cell. Performance improved by studies on the effect
on a single channels, double channels, cyclic single channels and symmetric singles channel serpentine flow field configurations to improve the gradual efficiency.

Table 3.2 Materials and specifications in PEM Fuel Cell

<table>
<thead>
<tr>
<th>S. NO.</th>
<th>PER AMETER</th>
<th>MATERIAL</th>
<th>DENSITY (kg/m³)</th>
<th>SPECIFIC HEAT (J/kg K)</th>
<th>THERMAL CONDUCTIVITY (W/m K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Membrane</td>
<td>Carbon sheet</td>
<td>7800</td>
<td>500</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Catalyst</td>
<td>Cadmium</td>
<td>8650</td>
<td>43</td>
<td>96.6</td>
</tr>
<tr>
<td>3</td>
<td>Current collector</td>
<td>Graphite</td>
<td>2240</td>
<td>44</td>
<td>168</td>
</tr>
</tbody>
</table>

4. ANALYSIS OF EXISTING (FLOW CHANNEL) MODEL

Rectangular is still the most commonly used cross-section channel design for bipolar plates. In this chapter existing model has been analysed and report is given below. The existing design is rectangular path rectangular section.

4.1 RECTANGULAR SECTION (SHARP CORNERS)

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>VELOCITY</th>
<th>VALUE (m/s)</th>
<th>CURRENT DENSITY (Amp/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Average velocity</td>
<td>0.2731</td>
<td>480.65</td>
</tr>
<tr>
<td>2</td>
<td>Maximum velocity</td>
<td>0.3308</td>
<td>581.68</td>
</tr>
</tbody>
</table>

The reason for the above behaviour may be due to the area surrounding the channel. The area surrounding the channel is determined and compared with the performance. The area of the solid surface in contact with the fluid flow influences the performance of the fuel cell. The larger the area the higher is the performance.

Table 4.1 Current Density Results
5. MODIFIED DESIGNS FOR SERPENTINE FLOW CHANNEL

5.1 CURVED PATH

(i) Semi-circular Section

(ii) Square Section

(iii) Triangle Section

Fig: 5.1 Various Cross Sections of Flow Channel

5.2 FILLET PATH

(i) Semi-circular Section

(ii) Square Section

(iii) Triangle Section

6. ANALYSIS RESULTS FOR MODIFIED DESIGNS

The velocity distribution find out for the case of the anode and cathode channel for serpentine flow field design. It shows the velocity distribution through the anode channel. The velocity increases gradually through the channel reach a maximum value at the anode outlet. The increasing in velocity is due to the generation of water vapor (H₂O) that produces form the electrochemical reactions occurred at the cell. For the velocity in the cathode channel, the velocity is decreased gradually form inlet to the outlet because of the consumption of the oxygen in the electrochemical reactions as shown in figure.

Table 5.1 Input Parameters

<table>
<thead>
<tr>
<th>S.No</th>
<th>PARAMETERS</th>
<th>ANODE</th>
<th>CATHODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fluid</td>
<td>Hydrogen</td>
<td>Oxygen</td>
</tr>
<tr>
<td>2</td>
<td>Mass flow rate</td>
<td>1.1410x10⁻⁸ kg/s</td>
<td>2.2870x10⁻⁷ kg/s</td>
</tr>
<tr>
<td>3</td>
<td>Flow</td>
<td>Turbulent</td>
<td>Turbulent</td>
</tr>
<tr>
<td>4</td>
<td>Static Pressure</td>
<td>1.01 bar</td>
<td>1.01 bar</td>
</tr>
<tr>
<td>5</td>
<td>Temperature</td>
<td>373 K</td>
<td>373 K</td>
</tr>
<tr>
<td>6</td>
<td>Density</td>
<td>4760 kg/m³</td>
<td>4640 kg/m³</td>
</tr>
<tr>
<td>7</td>
<td>Specific heat</td>
<td>377 J/kg K</td>
<td>377 J/kg K</td>
</tr>
<tr>
<td>8</td>
<td>Thermal conductivity</td>
<td>11.00 W/MK</td>
<td>2.370 W/mK</td>
</tr>
<tr>
<td>9</td>
<td>Specific heat ratio</td>
<td>1.404</td>
<td>1.395</td>
</tr>
<tr>
<td>10</td>
<td>Molecular mass</td>
<td>0.0020 kg/mol</td>
<td>0.0320 kg/mol</td>
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</table>
It is obvious that the maximum values occur at the interface between the cathode surface and current collector in which, the produced electrons pass through the shortest way to the outer surface of the cell and then to the external circuit. The distribution of the current density is by using formula.

6.1 ANALYSIS RESULTS

6.1.1. Semi-Circular Section (Fillet Path)

![Fillet Path](image)

Fig: 6.1. Semi-circular Section with Fillet Path (Hydrogen Flow)

![Fillet Path](image)

Fig: 6.2. Semi-circular Section with Fillet Path (Oxygen Flow)

6.1.2. Semi-Circular Section (Curved Path)

![Curved Path](image)

Fig: 6.3. Semi-circular Section with Curved Path (Hydrogen Flow)

6.1.3. Square Section (Fillet Path)

![Fillet Path](image)

Fig: 6.4. Semi-circular Section with Curved Path (Oxygen Flow)

![Fillet Path](image)

Fig: 6.5. Square Section with Fillet Path (Hydrogen Flow)

![Fillet Path](image)

Fig: 6.6. Square Section with Fillet Path (Oxygen Flow)
6.1.4. Square Section (Curved Path)

Fig: 6.7. Square Section with Curved Path (Hydrogen Flow)

Fig: 6.8. Square Section with Curved Path (Oxygen Flow)

6.1.5. Triangular Section (Fillet Path)

Fig: 6.9. Triangular Section with Fillet Path (Hydrogen Flow)

Fig: 6.10. Triangular Section with Fillet Path (Oxygen Flow)

6.1.6. Triangular Section (Curved Path)

Fig: 6.11. Triangular Section with Curved Path (Hydrogen Flow)

Fig: 6.12. Triangular Section with Curved Path (Oxygen Flow)

**CALCULATION**

In the field of electromagnetism, Current Density is the measurement of electric current (charge flow in amperes) per unit area of cross-section (m²). This is a vector quantity, with both a magnitude (scalar) and a direction.

**Current density, \( J = nV_d \text{e} \)**

Where,
\( n = 11 \times 10^{15} \text{ cm}^3 \), Carrier concentration (Constant Value)

\( V_d \) = Drift velocity in m/s

\( e = 1.6 \times 10^{-19} \text{ Coulombs, Charge of electron} \)

**Current density value for Semi circular section fillet path:**

**Average Velocity:**

\[
V_d = 0.8165 \text{ m/s} \\
J = 11 \times 10^{15} \times 0.8165 \times 1.6 \times 10^{-19} \times 10^6 \\
= 1437.04 \\
J = 1437.07 \text{ Amp/m}^2
\]

**Maximum Velocity:**

\[
V_d = 1.0066 \text{ m/s} \\
J = 11 \times 10^{15} \times 1.0066 \times 1.6 \times 10^{-19} \times 10^6 \\
= 1771.61 \\
J = 1771.61 \text{ Amp/m}^2
\]

7. RESULTS & DISCUSSION

7.1 VELOCITY Vs CURRENT DENSITY FOR VARIOUS SECTIONS

7.1.1 Semi-Circular Section (Fillet Path)

7.1.2 Semi-Circular Section (Curved Path)

7.1.3 Square Section (Fillet Path)

7.1.4 Square Section (Curved Path)

7.1.5 Triangular Section (Fillet Path)

7.1.6 Triangular Section (Curved Path)
we can observe that the performance of the PEMFC is improving with increasing velocity, and all the curves of polarization varies positively. The maximum current density evolves positively with increasing velocity because as the rate of chemical reaction is proportional to the velocity of hydrogen and oxygen. The validated parameters are then applied to the future designs.

- The geometry of the channel is changed from the rectangular shape to Square, Semi-circle and Triangular shapes and the performance of the fuel cell were observed. The Semi-circle and triangle channel has better performance when compared with the other channels. The reason for this may be due to the area that is in contact with the fluid flow.

**REFERENCES**


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<table>
<thead>
<tr>
<th>MODIFIED DESIGNS</th>
<th>SHAPE OF THE CHANNEL</th>
<th>FLOW PATH</th>
<th>AVERAGE VELOCITY (m/s)</th>
<th>AVERAGE CURRENT DENSITY (Amp/m²)</th>
<th>MAXIMUM VELOCITY (m/s)</th>
<th>MAXIMUM CURRENT DENSITY (Amp/m²)</th>
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</thead>
<tbody>
<tr>
<td>RECT ANGLE</td>
<td>SHARP CORNER</td>
<td>0.2731</td>
<td>480.65</td>
<td>0.3308</td>
<td>581.68</td>
<td></td>
</tr>
<tr>
<td>SEMI-CIRCULAR</td>
<td>FILLET</td>
<td>0.8165</td>
<td>1437.04</td>
<td>1.0066</td>
<td>1771.66</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CURVED</td>
<td>0.8264</td>
<td>1454.46</td>
<td>1.1172</td>
<td>1965.92</td>
<td></td>
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<tr>
<td>SQUARE</td>
<td>FILLET</td>
<td>0.3213</td>
<td>565.48</td>
<td>0.3754</td>
<td>660.70</td>
<td></td>
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<tr>
<td></td>
<td>CURVED</td>
<td>0.3412</td>
<td>600.51</td>
<td>0.4274</td>
<td>752.22</td>
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<tr>
<td>TRIANGLE</td>
<td>FILLET</td>
<td>0.9459</td>
<td>1664.78</td>
<td>1.3122</td>
<td>2309.47</td>
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<tr>
<td></td>
<td>CURVED</td>
<td>1.3688</td>
<td>2409.08</td>
<td>1.5823</td>
<td>2789.84</td>
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7.2 VALIDATION

From Table 7.1 we can observe that operating velocity of the fuel cell is varied and the resulting performance is observed. The performance of the fuel cell increases with increase in operating velocity. The increase in performance may be because of a better supply of reactants at higher velocities.

**CONCLUSION**

- The models for estimating PEMFC electrical power performance, is based on the description and modelling of over potential. The expression developed, is valid for a large interval of current density and involves factors related to the geometric design of PEMFC.

Table 7.1 Comparison of current density values

- The observations are consistent with the fact that the performance of the PEMFC is improving with increasing velocity, and all the curves of