AN OPTIMIZATION AND ANALYSIS OF FLOW FIELD GEOMETRY DESIGNS IN PROTON EXCHANGE MEMBRANE (PEM) FUEL CELL

Sathishkumar.S[1], Balamurali.S[2], Prakash.T[3], Praveenkumar.S[4]

[1] PG Scholar, Mechanical engineering, Vidyaa Vikas College of Engineering and Technology, Tamilnadu, India.
[2] Professor, Mechanical engineering, Vidyaa Vikas College of Engineering and Technology, Tamilnadu, India.
[3] Assistant Professor, Mechanical engineering, Vidyaa Vikas College of Engineering and Technology, Tamilnadu, India.
[4] Assistant Professor, Mechanical engineering, Shree Venkateshwara Hi-Tech Engineering College, Tamilnadu, India.

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 Pro-E and analyzed with ANSYS. The results are validated.

Keyword: - *Fossil fuel, Enervations, Reactant gases, Spherical, Quadrilateral, Acceleration, Current density*

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1. INTRODUCTION

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.

2. PROTON EXCHANGE MEMBRANE FUEL CELLS

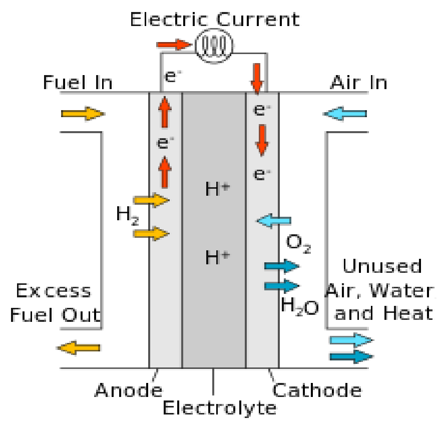


Fig. 2.1 PEM Fuel Cell

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.

2.1 EXISTING FLOW CHANNELS

Figure.2.2 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.

Table 2.1 Geometrical Parameters for Serpentine Flow Channel

S.NO.	DIMENSION	VALUE (m)
1	Gas channel length	20.00
2	Gas channel width	20.00
3	Diffusion layer height	0.3
4	Catalyst layer height	0.08
5	Membrane height	0.027
6	Current collector width	20.00
7	Current collector height	3.00

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 2.2 Materials and specifications in PEM Fuel Cell

S.NO.	PERAMETER	MATERIAL	DENSITY (kg/m^3)	SPECIFIC HEAT (J/kg K)	THERMAL CONDUCTIVIY (W/mK)
1	Membrane	Carbon sheet	7800	500	30
2	Catalyst layer	Cadmium	8650	43	96.6
3	Current collector	Graphite	2240	44	168

3. 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.

3.1 RECTANGULAR SECTION (SHARP CORNERS)

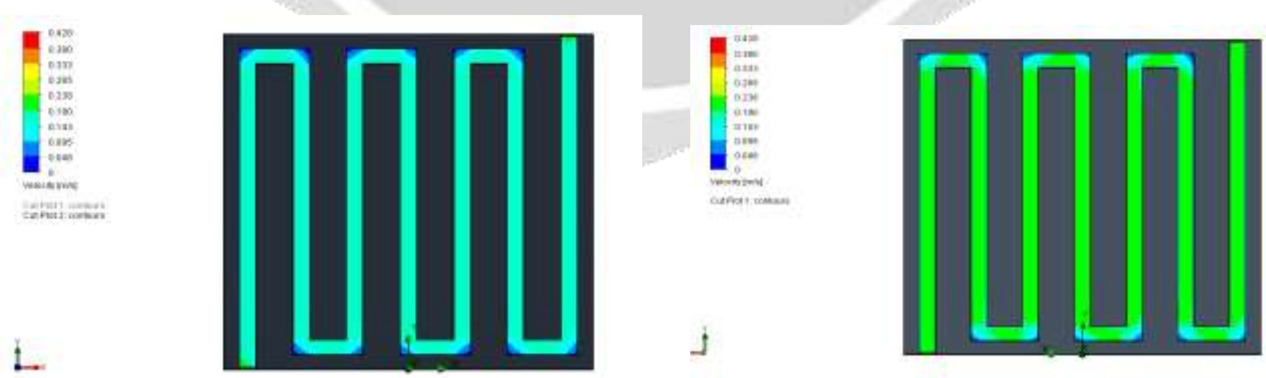


Fig 3.1 Rectangular Section with Sharp Corners (Oxygen Flow), (Hydrogen Flow)

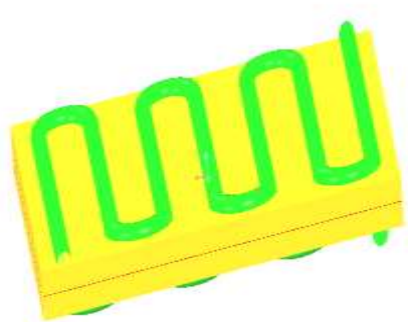
Table 3.1 Current Density Result

S.NO.	VELOCITY RANGE	VALUE (m/s)	CURRENT DENSITY (Amp/m^2)
1	Average velocity	0.2731	480.65
2	Maximum velocity	0.3308	581.68

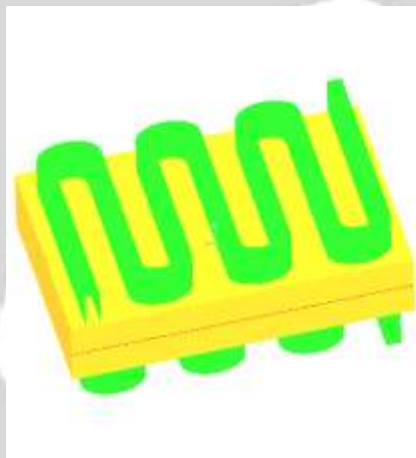
The reason for the above behaviour may be due to the area surrounding the channel. The area surrounding the channel is determined and compared with the performance. The area of the solid surface in contact with the fluid flow influences the performance of the fuel cell. The larger the area the higher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

4. MODIFIED DESIGNS FOR SERPENTINE FLOW CHANNEL

4.1 CURVED PATH



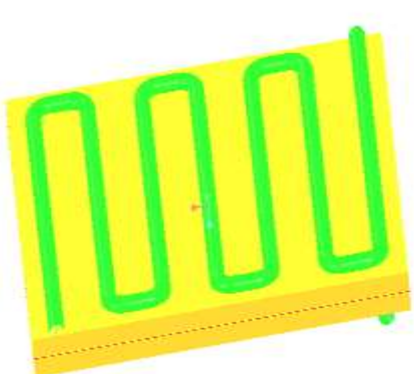
(i) Semi-circular Section



(ii) Square Section

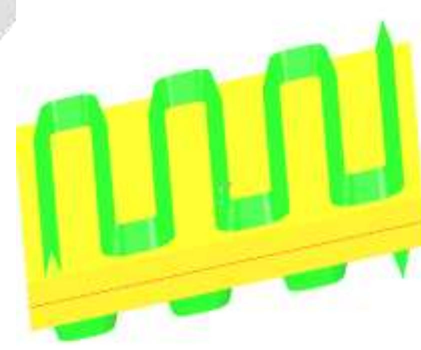
(iii) Triangle Section

4.2 FILLET PATH



(i) Semi-circular Section

(ii) Square Section



(iii) Triangle Section

5. 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 (H_2O) 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. 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.

Table 5.1 Input Parameters

S.No.	PARAMETERS	ANODE	CATHODE
1	Fluid	Hydrogen	Oxygen
2	Mass flow rate	1.1410×10^{-8} kg/s	2.2870×10^{-7} kg/s
3	Flow	Turbulent	Turbulent
4	Static Pressure	1.01 bar	1.01 bar
5	Temperature	373 K	373 K
6	Density	4760 kg/m^3	4640 kg/m^3
7	Specific heat	377 J/kg K	377 J/kg K
8	Thermal conductivity	11.00 W/mK	2.370 W/mK
9	Specific heat ratio	1.404	1.395
10	Molecular mass	0.0020 kg/mol	0.0320 kg/mol

5.1 ANALYSIS RESULTS

5.1.1. Semi-Circular Section (Fillet Path)

Fig 5.1.Semi-circular Section with Fillet Path (Hydrogen Flow), (Oxygen Flow)

5.1.2. Semi-Circular Section (Curved Path)

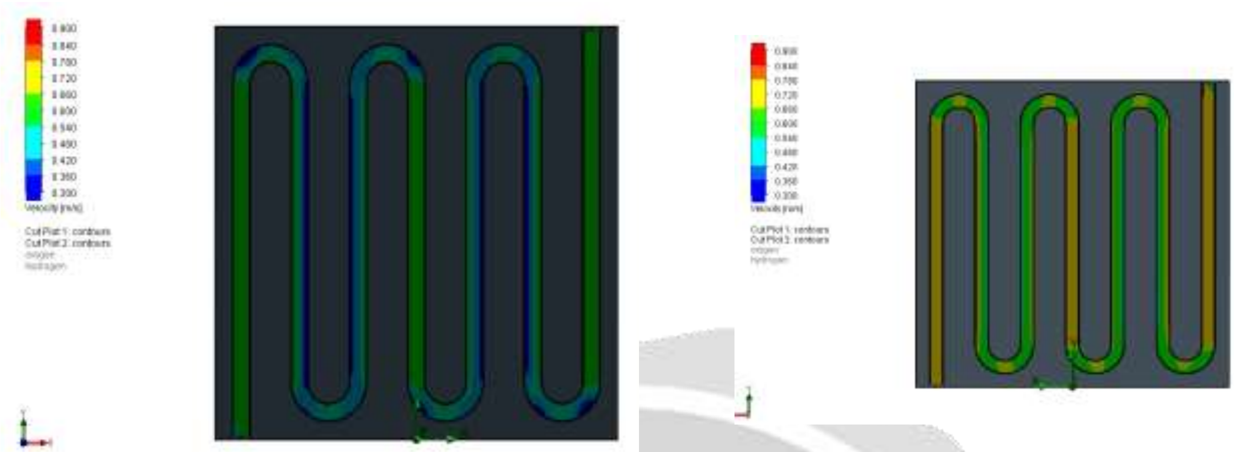


Fig 5.2.Semi-circular Section with Curved Path (Hydrogen Flow), (Oxygen Flow)

5.1.3. Square Section (Fillet Path)

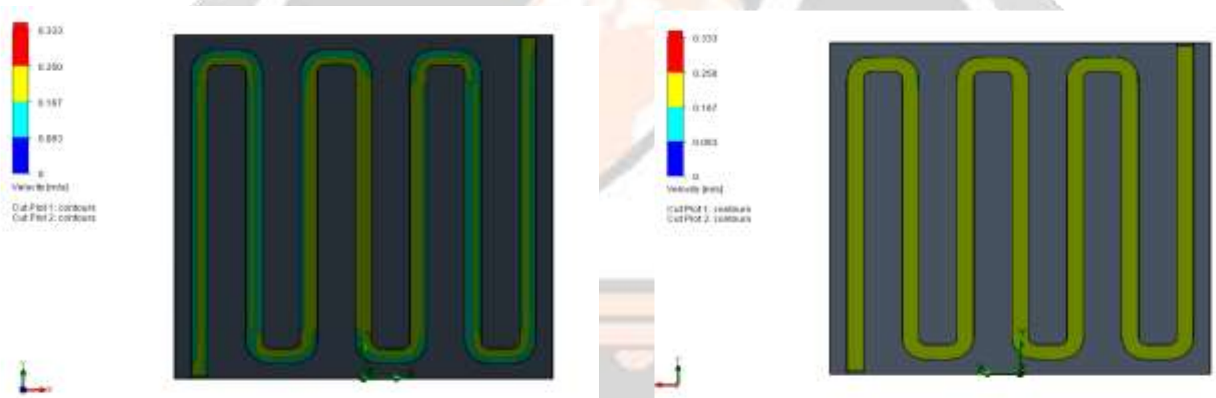


Fig 5.3.Square Section with Fillet Path (Hydrogen Flow), (Oxygen Flow)

5.1.4. Square Section (Curved Path)

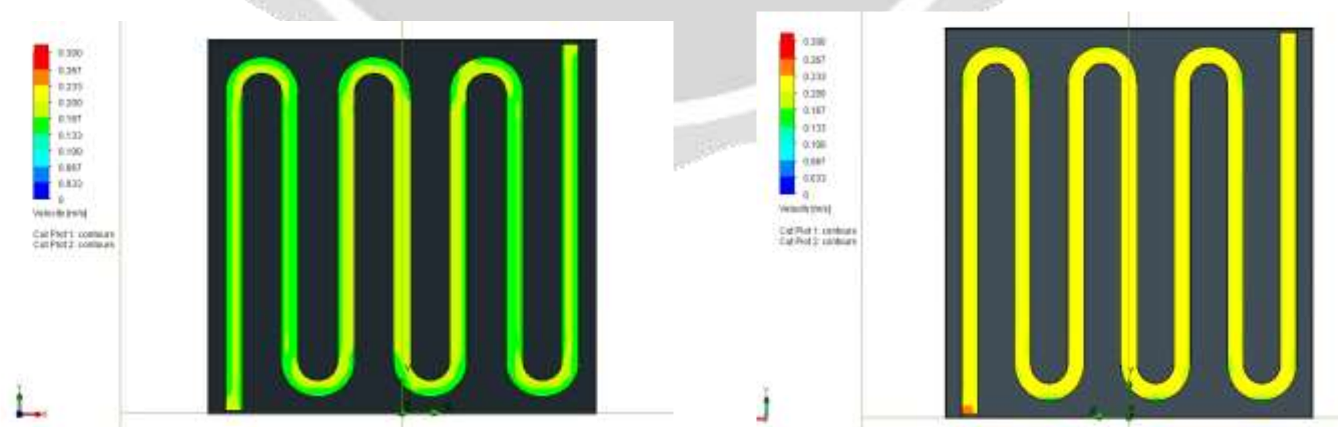
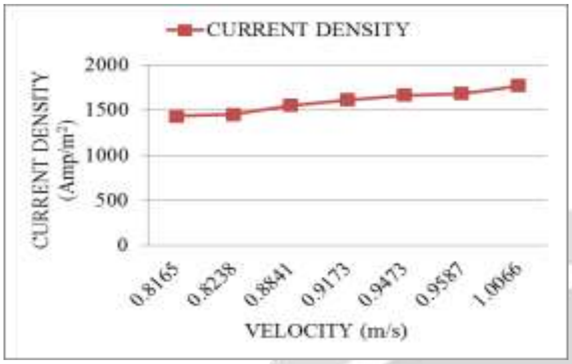


Fig 5.4.Square Section with Curved Path (Hydrogen Flow), (Oxygen Flow)

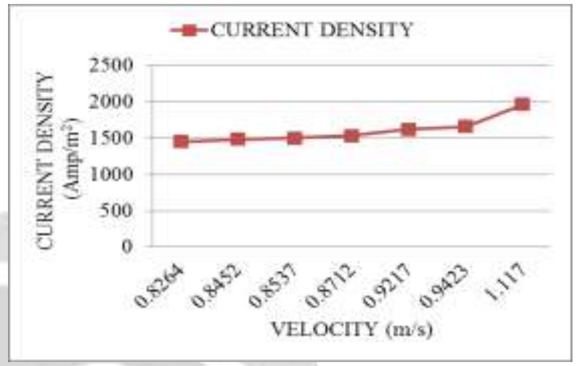
6. RESULTS & DISCUSSION

6.1 VELOCITY Vs CURRENT DENSITY FOR VARIOUS SECTIONS

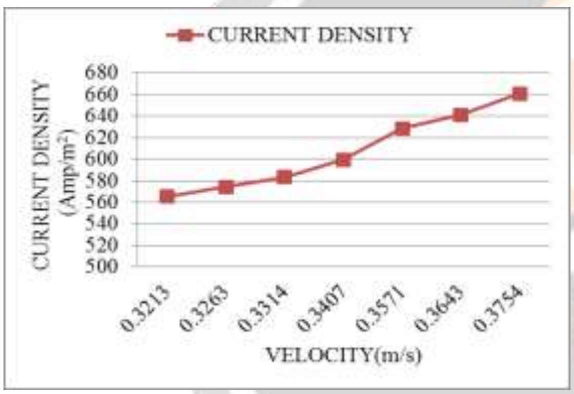
6.1.1 Semi-Circular Section (Fillet Path)



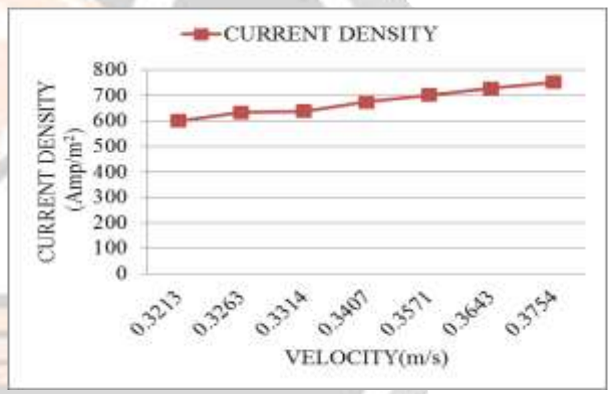
6.1.2. Semi-Circular Section (Curved Path)



6.1.3 Square Section (Fillet Path)



6.1.4 Square Section (Curved Path)



6.2 VALIDATION

DESIGNS	SHAPE OF THE CHENNAL	FLOW PATH	AVERAGE VELOCITY (m/s)	AVERAGE CURRENT DENSITY (Amp/m^2)	MAXIMAM VELOCITY (m/s)	MAXIMUM CURRENT DENSITY (Amp/m^2)
EXISTING DESIGN	RECTANGLE	SHARP CORNER	0.2731	480.65	0.3308	581.68
MODIFIED DESIGNS	SEMI-CIRCULAR	FILLET	0.8165	1437.04	1.0066	1771.66
		CURVED	0.8264	1454.46	1.1172	1965.92
	SQUARE	FILLET	0.3213	565.48	0.3754	660.70
		CURVED	0.3412	600.51	0.4274	752.22
		CURVED	1.3688	2409.08	1.5823	

Table 6.1 Comparison of current density values

From Table 6.1 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.

7. CONCLUSIONS

- 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.
- The observations are consistent with the fact 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.

8. REFERENCES

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