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Experimental studies of PEM fuel cell - review for different flow field design

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Abstract - Proton Exchange Membrane Fuel Cell (PEMFC) is a promising force creating gadget with high proficiency, zero outflows and working at environmental temperature and weight. The execution of the power device is profoundly impacted by the working parameters like temperature, weight, stickiness and mass stream rates of reactant gases; and the plan parameters like stream channel outlines and measurements, rib estimate, channel length, thickness and porosity of GDL, film write, point and so forth.

Keywords: PEM fuel cell, flow field design, performance increases

I. INTRODUCTION

The environmental pollution of the world is increasing day by day due to the use of fossil fuels by the automobiles and some power generating systems. So there is a necessity to find out the alternate power sources. The fuel cells are one of the high efficient power generating sources with zero/very low emissions.Fuel cell is an electrochemical device which converts chemical energy of fuel into electricity, heat and water. Due to the exothermic reactions, heat is generated from the fuel cell. Based on the operating temperature, fuel cells are classified into low, medium and high temperature fuel cells. Compared to all other fuel cells, the Proton Exchange Membrane fuel cells (PEMFC) are having high efficiency and working at atmospheric temperature and pressure.

The Hydrogen Oxidation Reaction (HOR) is carried out in the anode side and Oxygen Reduction Reaction (ORR) is carried out in cathode side as follows in the proton exchange membrane fuel cell.

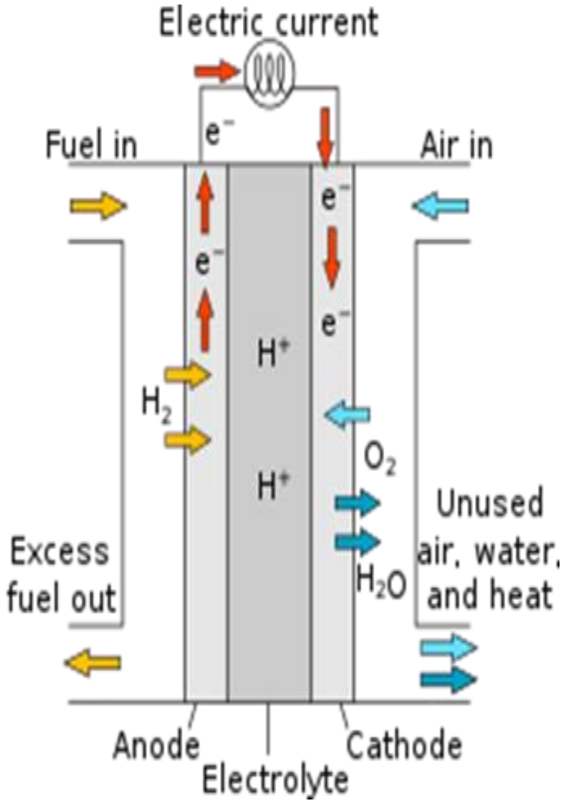

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Fig. 1 PEM Fuel Cell

Anode side: $H2 \rightarrow 2H+ + 2e-$
Cathode side: $2H+ + 2e- + \frac{1}{2}O2 \rightarrow H2O$
Reaction: $H2 + \frac{1}{2}O2 \rightarrow H2O$ + Electricity + Heat

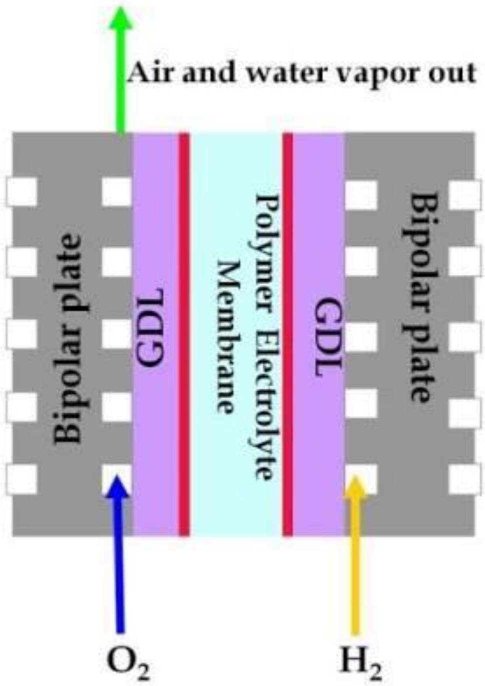

Fig. 2 PEM Fuel Cell layout

Nomenclature
Symbols
e- Electrons
H+ Protons
H2 Hydrogen
H2O Water I Current density (mA/cm2)
O2 Oxygen
P Power density (mW/cm2)
V Cell potential (V)

Abbreviations
GDL Gas Diffusion Layer
LxC Landing to Channel width
MEA Membrane Electrode Assembly PEMFC Proton Exchange Membrane Fuel Cell

Flow-field layout design

One of the main obstacles to large-scale commercialization of fuel cells is the gas flow fields and BPPs, including the development of low-cost lightweight construction materials, optimal design and fabrication methods and their field impact on PEMFC performance (i.e., energy efficiency and power density). As much as 50% increase in the output power density has been reported just by appropriate distribution of gas flow fields alone.

In spite of all the industrial R&D efforts, the time-effective design and optimization of the gas flow fields and BPPs remain one of the important issues for the cost reduction and performance improvement of PEM fuel cells .As to the geometrical configurations of the gas flow fields, a variety of different designs are known and the conventional designs typically comprise either pin, straight or serpentine designs of flow-field channels. Fuel cell developers have used alternative designs, such as shown fig [3],

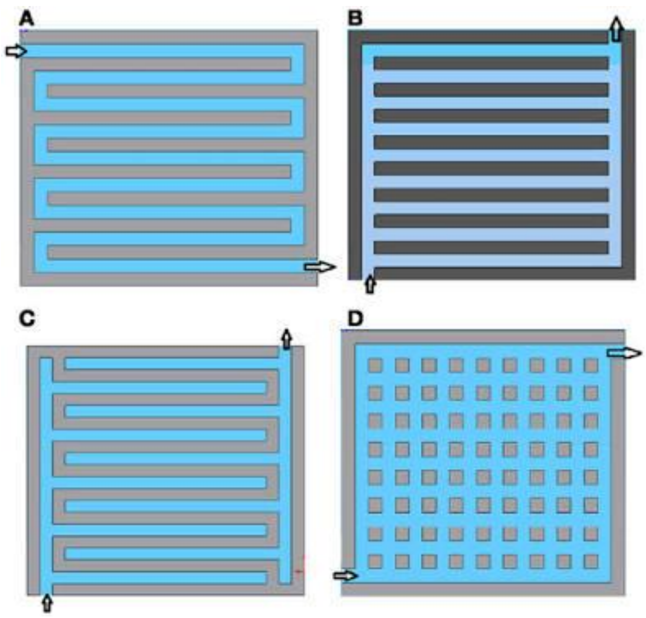

Fig. 3 Flow field diagram

1. Pin-type flow field,
2. Series-parallel flow field,
3. Serpentine flow field,
4. Integrated flow fields,
5. Interdigitated flow field,

1. Pin-Type flow field

The pin-type flow fields are illustrated by Sawyer andRaiser. The flow-field network is formed by many pins arranged in a regular pattern, and these pins can be in any shape, although cubical and circular pins are most often used in practice. Normally, both the cathode and the anodeflow-field plates have an array of regularly spaced cubical or circular pins protruding from the plates, and the reactant gases flow across the plates through the intervening groove formed by the pins. The actual fluid flow thus goes through network of series and parallel flow paths. As a result, pin design flow fields result in low reactant pressure drop.

However, reactants flowing through such flow fields tend to follow the path of least resistance across the flow field, which may lead to channelingand the formation of stagnant areas, thus uneven reactant distribution, inadequate product water, such as show fig [4],

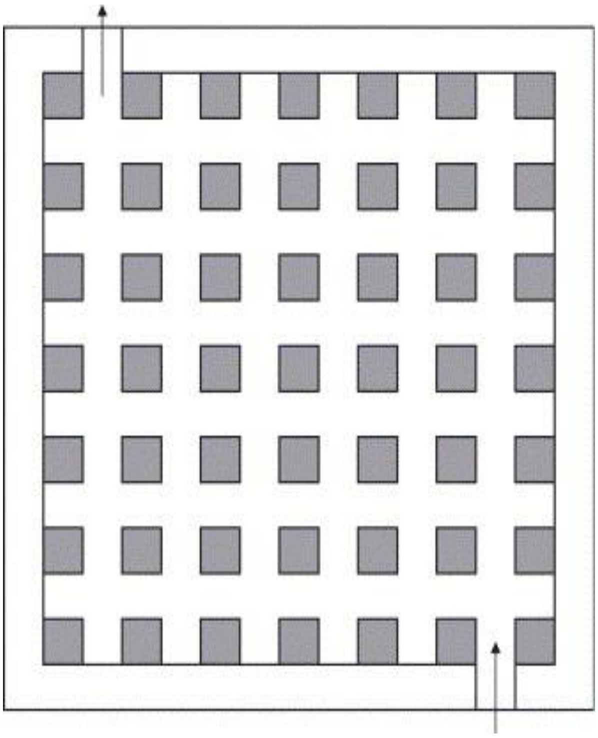

Fig. 4 Pin-Type flow field

Removal and poor fuel cell performance. Further, relative's table recirculation zones may arise behind each pin since the reactant flow is very slow in such a small flow channels, and the Reynolds number for the reactant flow remains small, particularly for the fuel stream Reynolds numbers may range from a few tens to low hundreds.

Reactant concentration may be depleted in the stable recirculation zones as well, decreasing the cell and stack performance. These issues may become particularly problematic with flow fields having certain geometric shapes.

2. Straight flow field

A straight flow-field design, the gas flow-field plate includes a number of separate parallel flow channels connected to the gas inlet and exhaust headers, which are parallel to the edges of the plate .with the flow channel cross sectional shape.

When air is used that low and unstable cell voltages occur after extended Variation of configuration in straight or parallel flow field design periods of operation, because of cathode gas flow distribution and cell water management.

As the fuel cell operated continuously, the water formed at the cathode accumulates in the flow channels adjacent to the cathode, the channels become wet, and the water thus tends to cling to the bottom and the sides of the channels. Another problem associated with this design is that the straight and parallel channels in the BPPs tend to be relatively short and have no directional changes.

As a consequence, the reactant gas has a very small pressure drop along these channels, and the pressure drop in the stack distribution manifold and piping system, which is normal to the BPPs, tends to be large in comparison. This inadequate pressure loss distribution results in non-uniform flow distribution of reactant gases among various active cells in the stack, usually the first few cells near the manifold inlet have more flow than those towards the end portion of the inlet, such as shown fig [5],

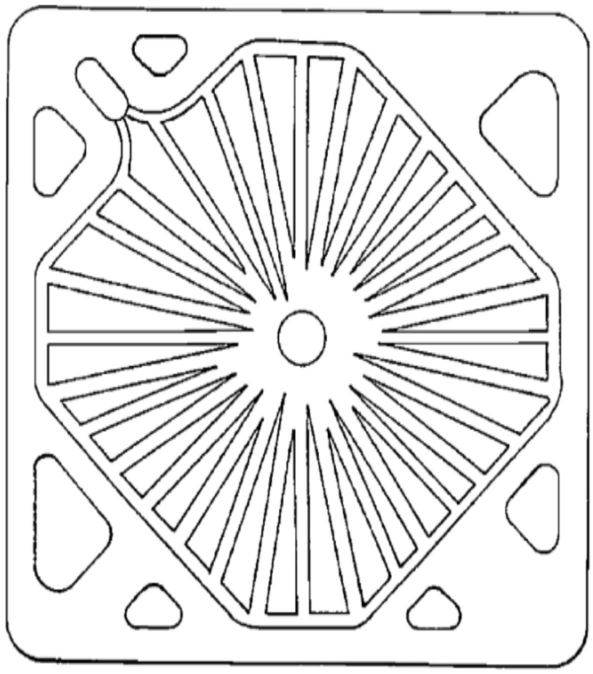

Fig. 5 Straight flow field

3. Serpentine flow field

The channels are generally linear and arranged parallel to one another, but skewed to the edge of the plate, while the spaced slots allow cross-channel flow of the reactant gas in a staggered manner, which creates a multiple of mini-serpentine flow paths transverse to

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the longitudinal gas flow along the channels. Such as shown fig [6],

Thus, adjacent pairs of the channels are interconnected by the spaced slots. The flow channels on the anode and cathode plates are skewed in opposite directions in such a manner that exact co-flow arrangement is avoided, and some cross flow and some nearly co-flow configuration are achieved

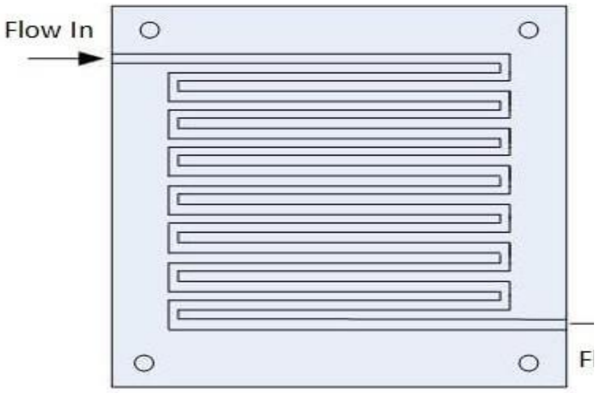

Fig. 6 Serpentine flow field

Although multiple serpentine flow-field designs of this type reduce the reactant pressure drop relative to single serpentine designs, the reactant pressure drop through each of the serpentines remains relatively high due to the relatively long flow path of each serpentine channel, thus the reactant concentration changes significantly from the flow inlet region to the exit region for each active cell.

4. Integrated flow field

A fluid flow-field plate assembly, which is divided into a multiple of fluid flow sub-plates that each sub-plate is electrically insulated from all other sub-plates of the same plate assembly, and has its own reactant flow field adjacent to the electrochemically active area of the nearby MEA. A cooling flow field may be positioned in-between and around each of the gas flow sub-plates.

However, these designs cannot maintain a uniform temperature distribution over the entire fuel cell surface such as shown fig [7],

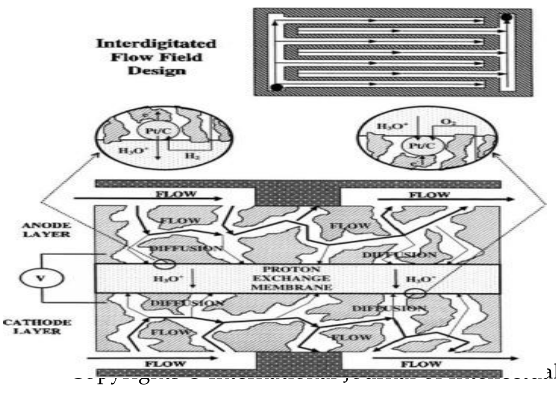

Fig. 7 Integrated flow field

5. Interdigitatedflow field

For all the above designs of flow fields, the flow channels are fabricated on the flow distribution plates (or BPPs), or to the lesser degree, on the porous electrode backing layers, and they provide continuous flow passages, from the stack inlet manifold to the exit manifold, while traversing through the electrode surface of the active areas of the cell. In this configuration, the dominant reactant flow is in the direction parallel to the electrode surface, and the reactant flow to the catalyst layer, required for electrochemical reaction and electric power generation, is predominantly by molecular diffusion through the electrode backing layer.

Therefore, interdigitated flow fields have been explored to provide convection velocity normal to the electrode surface for better mass transfer, and convection flow in the porous backing layer for enhanced water removal capability consists of dead-ended flow channels built on the flow distribution plates. When a fuel cell accumulates too much water at high current density, about one-third of the electrode surface area is not utilized .To overcome mass transport limitations in porous electrodes, the diffusive mass transfer mechanism is changed into a forced convective mass transfer which causes limiting current density and maximum power density to increase significantly such as shown fig [8],

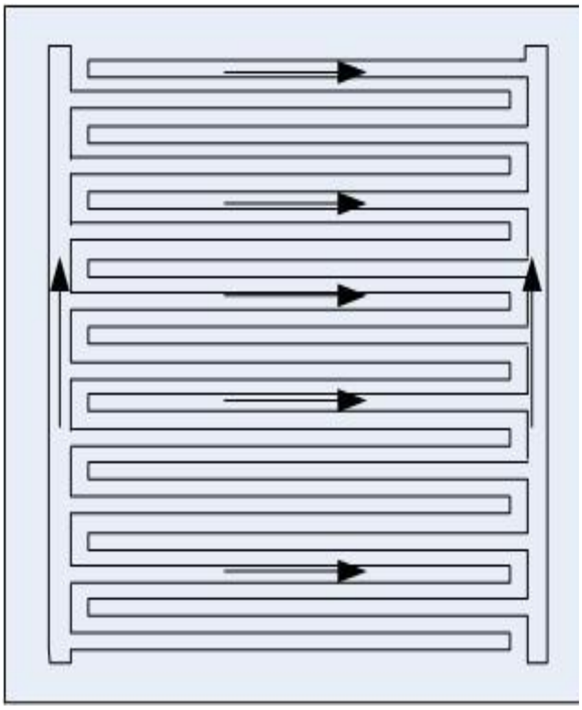

Fig. 8 Interdigitated flow field

This design outperforms conventional flow-field design, especially on cathode side at high current densities.

II.LITERATURE SURVEY

[1] Toghyani. S, Afshari. E, Baniasadi. E,Atyabi. S.Amade et al. an investigation on various five stream field designs like parallel, single way serpentine, double way serpentine, triple way serpentine and fourfold way serpentine and inferred that serpentine stream field give better dispersion of current thickness and furthermore shows that 2-way designs is generally profitable as far as weight drop.

[2] E.Alizadeh, M. Rahimi-Esbo, S.M. Rangoshay, S.H.M. Saadat, M.Khorshidian et al. says that the conveyance of gases in PEMFC assumes a crucial part in ebb and flow thickness, temperature appropriation and water administration. Another course write serpentine stream field is presented and the outcome demonstrates that the stream field delivers a uniform momentum thickness and furthermore water administration is moved forward.

[3] D.H. Jeon, S. Scenic route, S. Shimpalee, J.W. Van Zee et al. have found that. At high delta stickiness, the twofold channel stream field was foreseen to have better polarization execution and uniform current thickness and At low inlet dampness, the cyclic single channel and symmetric single channel stream field would have advantage for generous scale system.

[4] M. Rahimi-Esbo, A.A. Ranjbar, E. Alizadeh and M. Aghaee et al. have made seven stream fields are 1-Serpentine, 2-Serpentine, 3-Serpentine, 2-1-Serpentine, 3-2-Serpentine, 4-3-Serpentine and 5-4-Serpentine. Their outcome demonstrates that 2-1-Serpentine stream field has the most astounding execution particularly at high current densities and established that working voltages more than 0.5V.

[5] Yupeng Yang, Xu Zhang, LiejinGuo, and Hongtan Liu et al. have found a three stream fields are parallel, serpentine and interdigitated. The outcome demonstrates that interdigitated stream field has most stable cell execution under both steady weight and swing supply hubs.

[6] E. Afshari, M. Mosharaf-Dehkoridi, H. Rajabian et al. have made three sort of stream channels are Two parallel stream channels, Locally bewilder limited stream channels and Metal froth as a stream wholesaler. The outcome demonstrates that metal froth expands oxygen focus and current thickness.

[7] Tamerabet Monsaf, Ben Moussa Hocine, Sahli Youcef, Mohammedi Abdallah et al. have influenced a winding stream to handle outline. Their outcome demonstrates that winding stream field impacts the cell execution, the higher contact zone amongst channel and GDL.

[8] Moosa Ashrafi, Mehrzad Shams in their exploration, 3D numerical model is proposed in view of VOF technique. They recreate the exertion of gravity on the gas-fluid two-stage stream in a full-scale single-serpentine stream field. The outcome demonstrates that the directs are situated in evenly and channel complex is inserted on upper side of the stream field and the weight drop is most reduced.

[9] Hamilton,Hsieh Shushing, Huang Yi-Ji et al. In this design, the gas flow-field plate includes a number of separate parallel flow channels connected to the gas inlet and exhaust headers, which are parallel to the edges of the plate.

[10]Johnson,Zhang Guan sheng, Mama Container, GooLie-in, Liu Hong tan et al. design with pressure

gradients within the channels, such that the resistance to reactant flow differs along the length of the adjacent channels.

[11]Yang,Liu Hongtan et al. Introduced restrictions between the inlet of the manifold and inlet of the straight channels which in turn contribute towards pressure differential without using long.

[12]Spurries,Feser JP, Prasad AK, Advani SG et al. Granada and Woodley, Described a modified serpentine gas flow field across the plate surface. In an attempt to tackle the problems with straight channels.

[13]Shimpalee. S, Greenway. S, Van Zee. J.W et al. pointed out that several continuous separate flow channels might be used in order to limit the pressure drop and thus minimize the parasitic were required to pressurize the air, can be as much as over limit of the stack power output. Reported that under the same experimental conditions, the output power from the cell could be increased by almost 50% with this new type of flow-field plates.

[14]Chow,Li H, Tang Y et al. Released a BPP design, which possesses both reactant gas flow field and cooling flow field on the same plate surfaces .The gas flow field directly faces the electrochemically active area of the Adjacent MEA, while the cooling flow field surrounds the gas flow field. This integrated reactant and coolant flow-field plate design eliminates the need for a separate cooling layering a stack, thus significantly improves the stack power density.

[15]Ernst and Middleman et al. described a fluid flow-field plate assembly, which is divided into a multiple of fluid flow sub-platesthat each sub-plate is electrically insulated from all other sub-plates of the same plate assembly, and has its own reactant flow field adjacent to the electrochemically active area of the nearby MEA. A cooling flow field may be positioned in-between and around each of the gas flow sub-plates .However, these designs cannot maintain a uniform temperature distribution over the entire fuel cell surface.

III. CONCLUSIONS

In this work, the primary concentration was to locate the ideal working conditions, including humidification temperature, cell temperature and cathode gulf gas stream rate, for the PEM energy units with various stream fields and look at the impacts changed stream fields(flowchannelnumber,flow channel length, corner numbers and perplex impacts) on the cell execution under various working conditions. Correlation among the PEM power devices with ordinary stream field outlines uncovers that, with an expansion in the stream channel number, the stream channel length and the corner number in a serpentine stream field, the electrochemical response is raised. Therefore, it is helpful to finish the utilization of the provided fuel and upgrade of the cell execution as air is the cathode gas.

The PEM energy unit with a parallel stream field has three times a bigger number of channels than the serpentine stream field, along these lines it gives a superior capacity of gas dissemination in the stream field at the state of low current thickness.

While at the working state of high current thickness, the corner regions inside the serpentine flow fieldaugmentsthemass Tran protonthere octant gas and in this manner improves the general cell execution.

Along these lines, in customary stream field outlines, proper stream channel numbers, stream channel lengths and corner numbers could viably enhance the cell execution. Concerning the ideal parameters, the PEM energy component with a parallel stream field with a puzzle demonstrates a superior cell execution because of the bewilder impact which powers the reactant gas through the gas diffuser layer under ideal working conditions, and less reactant gas is required than in regular stream field outlines. Notwithstanding, a bigger number of stream channels suggests a slower fuel transport rate inside the stream field and a more total response. So in bury digitized stream field outlines, the PEM power module with a parallel stream field with perplex can give a superior energy unit execution than that with a Z-type stream field with confound. The impact of fluid water on the power device activity between the diverse stream field outlines is additionally vital and will be researched sooner rather than later.

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