Domestic Research Status of PEM Fuel Cell Serpentine Flow Field Plate

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Abstract. Serpentine flow field is one of the most research values of the flow field in the form; it has a good overall performance. According to the number of flow fields it can be divided into single serpentine flow field, dual serpentine flow field, multi-field serpentine flow field and the like. Under the foundation of studying a large number of domestic journals, papers and textbooks the current domestic research on serpentine flow properties were summarized. The nature and character of single serpentine flow field, dual serpentine flow, etc. were analyzed. It can provide a feasible reference for the structural design and research directions of flow field of proton exchange membrane fuel cell.

Key words: serpentine flow field; proton exchange membrane (PEM) fuel cells; flow field plate

Introduction

Energy is the driving force of economic development, and it is also an important indicator to measure a country's comprehensive national strength, development level of the civilization and people's living standards. Fuel cells are a highly efficient, environmentally friendly power generation device, which will translate the chemical energy stored directly in the fuel and oxidizer into electrical energy. In addition to the general characteristics of PEM fuel cell, it also has a fast start at room temperature, no electrolyte loss, easy to drain the water, long life, power and specific energy higher than the outstanding features [1-6].The bipolar plate is an important component of the fuel cell, the design of the fuel cell is largely bipolar plate design, and especially the design of the flow field is a top priority [7].

1. Serpentine flow field

Serpentine flow field is one of the most common and most studied forms of the flow field. According to the number of inlet tract, it can be divided into single serpentine flow field, dual serpentine flow field, multi-field serpentine flow field and the like. As shown in Figure 1 [8]:

Figure 1. Flow Field Model: a) Serpentine flow field (single); b) Serpentine flow field (double); c) Serpentine flow field (multiple).
1.1. Single serpentine flow field. According to characteristics of single serpentine flow studied by the research staff, we found the results as follows. In the inlet and outlet found that the pressure difference of single serpentine flow field at cathode is far greater than the capillary force of water $f$, water in the flow path can be discharged smoothly; anode outlet pressure difference is also greater than water capillary force $f$, generated water in flow path can be smoothly discharged[9]. As it can be seen from the above conclusion, single serpentine flow field indeed avoid "flooding" phenomenon.

Reverse inlet manner in cathode can facilitate reactant and product evenly distributed within the cell, the performance of fuel cell improves. Hydrophilic runner wall has a major impact on gas and water transport, although hydrophobic wall drainage fast, but not conducive to the mass transfer of reaction gas[10]. In the discussion if it is the same on the situation in various regions of the fluid flow path flows, the researchers found in both sides of the flow field near the wall where the fluid velocity is almost zero, there was a large velocity gradient; and the intermediate flow field has the maximum speed, the minimum velocity gradient[11]. Improved humidification conditions can increase the impact of change on performance of fuel cell; the change of anode humidification condition has more influence on fuel cell performance than the change of cathode humidification conditions[12]. Found from Gang Qiang study, humidifier can improve the performance of PEM fuel cells, the same temperature and pressure which affect fuel cell performance [13].

1.2. Dual serpentine flow field. At the study of characteristics for dual serpentine flow fields, Fan Chaobing proposed a very innovative experimental program. In the reverse inlet simulation experiments, liquid water and water vapor saturation concentration changes were analyzed at low current density, mid-low current density and high current density. At low current, the gap of density is not great compared with synchrony inlet, largely depends on the electrochemical reaction. At the same time, when the current density increased, two kinds inlet average moisture content of the membrane plane became saturated, the membrane also began to decrease water absorption capacity, so there is no much difference of two kind’s inlet. Analysis found that parallel single serpentine flow field can reduce the water shortage situation in the cell at low current densities; the flow path can avoid "flooding" situation at high current density.

Cathode reverse inlet and parallel arrangement of a single serpentine flow field can make liquid water and water vapor distribution distribute more uniform in the inner cell, it will not only improve the water vapor average at low current density concentration, reducing the concentration of water vapor at high current density, but also to avoid the "flooding" of high current density and the water shortage of low current density.

1.3. Multi-field serpentine flow field. The so-called multi-field serpentine flow field is similar to that consisting of a plurality of single serpentine flow fields side by side. About the flooding, Yu Yi found in the study that under conditions of low current density, multi-field serpentine flow field would have flooding of danger in cathode; while at high current densities, flooding can be avoided. But for the anode, the electrode can also be flooded. The increased of shoulder width can reduce the opening rate, increasing the internal resistance and reduced the performance of the fuel cell. From the experimental results it found that either high power density regions or low density regions, fine of serpentine flow field would be beneficial to the electrochemical reaction performed [14, 15]. And Tan Yawei also done similar experiments, he found that with the number of ribs and flow fields increased, the performance of fuel cell would be improved. With the increasing of flow field depth,
the performance of fuel cell substantially no change in the activation polarization region and the ohmic polarization region, but in the area of concentration polarization, the performance of fuel cell was improved.

Research on the impact of increasing the input pressure of the gas and fuel cell placement, it found that increasing the air pressure to improve the performance of the fuel cell was better than the effect of increasing the hydrogen pressure. Current density was an important parameter of the fuel cell performance, in the study of a small size single cell, it found that the current density was more evenly distributed throughout the plane and decreased along the direction of flow field [16]. In the study we found that cathodic oxygen component concentration was substantially decreasing trend due to the reaction of the inlet to the outlet consumes, while the consumption of hydrogen in anode was the opposite [17].

On the basis of the above content, Chen Shizhong [18] simulated the combination of ordinary serpentine flow field and gradient serpentine flow field by using the multiphysics coupling analysis software. It found that in the case of the same voltage, gradient serpentine flow field had the highest current density, followed by mixing flow field 1, ordinary serpentine flow field again, and mixing flow field 2 had the minimum current density. When the voltage was constant, the fuel cell output power proportional to the current density. In the study of pressure changed at cathode, it found that pressure changed and oxygen concentration changed had the same trend along the gas flow direction. Jian Qifei [19] gave a relatively optimal porosity; its value was about 0.375. A pressure variation in the cathode and anode flow field was uniform, no abrupt change. When people in-depth studied the flow field, at the same time, some people considered if the thickness of the membrane would be affected [20].

2. Evolution of the serpentine flow field

Currently the form of serpentine flow field cannot meet the increasing demands of performance, after careful design and reasonable calculus researchers, evolved out of the many different kinds of serpentine flow fields. As shown in figure 2 [21-23].

![Figure 2. Evolution serpentine flow field: a) Spiral flow field; b) Combined flow field; c) Combined flow field.](image)

2.1. Spiral flow field. Spiral flow field was a novel form of the flow field based on the serpentine flow field; it not only had the features and advantages of the serpentine flow field, but also had its own unique flow field type and performance. Research on the spiral flow field currently still in infancy, Wang Hongxing thought that the spiral flow field was very similar to serpentine flow field, had a strong drainage function. However, the spiral flow field staggered near the inlet and near the outlet of the flow field, so that the concentration distribution of reaction gas and water was more
uniform the spiral flow field, this was the advantages that serpentine flow field didn’t have.

2.2. Combined flow field. For the study of the combination flow field, in the study of combination flow field performance, Tanya Wei designed three different experimental analysis of the flow field plate, concluded that a combination of the flow field plate consist by three flow fields had the best performance, while the combination of the flow field plate consist by five flow fields had the worst performance. Wherein the biggest performance difference area was in ohmic polarization area, performance differences were reduced in concentration polarization area. In terms of air flow distribution and pressure loss, the snake straight mixed flow fields changed the original straight field air distribution, so that they were uniform in terms of air distribution and reduced differential pressure between import and export. Pressure loss of snake straight mixed flow fields was much smaller than serpentine flow field.

3. Comparison and analysis

Table 1. Comparison of advantages and disadvantages of the flow field.

<table>
<thead>
<tr>
<th>Serpentine flow field</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Single serpentine flow field</td>
<td>Import and export pressure difference was big in cathode and anode, and it was conducive to the discharge of water to avoid the flood phenomenon.</td>
<td>Large gas pressure drop, more energy consumption and uneven distribution of the reactant, flow field wall had some resistance for water transmission.</td>
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<tr>
<td>Dual serpentine flow field</td>
<td>Reverse inlet in cathode made oxygen distributed evenly, improved average molar concentration of oxygen in the electrode, conducive to the discharge of water; the water content in membrane increased and then decreased the proton transfer resistance.</td>
<td>Gas pressure drop was large, energy consumption increased; the flow field wall had some resistance to water transmission.</td>
</tr>
<tr>
<td>Multi-field serpentine flow field</td>
<td>The number of flow field increased further improved the porosity, current density distributed more uniform in the entire plane, and along the direction of flow it was declined trend.</td>
<td>Processing was complicated, high cost, the anode may be flooded, the flow field was too long, pressure drop was big, high energy consumption, uneven distribution of the reactants, and the wall resistance was increased.</td>
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## Evolution of the serpentine flow field

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<tr>
<th>Spiral flow field</th>
<th>Combined flow field</th>
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<tr>
<td>A strong drainage and concentration of the reaction gas released more evenly throughout the flow field.</td>
<td>Varied forms can be designed, with strong rationality on gas distribution, reducing the pressure drop of import and export; water management also had certain advantages.</td>
</tr>
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<td>Hydrophilic flow field wall increased the resistance of gas transmission, energy consumption increased.</td>
<td>Processing was complicated, expensive, difficult to manufacture, hydrophilic of the flow field wall increased the resistance, energy consumption increased.</td>
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### 4. Conclusions

1) To reduce the width and depth of flow field would help improve the fuel cell performance and current density, moderate decreases width of shoulder can also improve the fuel cell performance.

2) Considering the size of the flow field plate and the internal resistance, the best opening ratio was about 60%.

3) Reducing the number of flow fields modestly, it can not only avoid the large pressure drop, but also can avoid flooding phenomenon, also reduces energy loss.

4) It was found in the conventional serpentine flow fields that the fine flow field can increase the gas flow rate, and then it can take away the excess water to prevent clogging of the flow field.

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### References


