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Development Status of Flow Field Design for Bipolar Plates in Hydrogen Fuel Cells

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This article provides a detailed introduction to the current development status of flow field design for hydrogen fuel cell bipolar plates, analyzes the impact of traditional and new flow field designs on fuel cell performance, and explores innovative designs such as biomimetic flow fields and three-dimensional flow fields through numerical simulation and experimental verification by domestic and foreign researchers. Some scholars have also studied the effect of adding protrusions, sub channels, or groove structures in the flow channel on improving the performance of fuel cells.This article provides the latest progress and recent research results in the flow field design of hydrogen fuel cell bipolar plates for future researchers. These contents have important reference value and guiding significance for researchers to further explore new flow field designs and improve flow field structures.

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1. INTRODUCTION

Global warming caused by greenhouse gas emissions, environmental pollution caused by industrialization, and the continuous reduction and depletion of natural energy resources pose an imminent threat to modern society [1]. Many countries are working to promote the transition of their energy systems from fossil fuels to low-carbon or carbon-free energy production [2]. Especially in the context of complex global geopolitics and ongoing local and regional conflicts, the global production and consumption structure of traditional fossil fuels and renewable energy will be reshaped by [3]. Countries around the world are gradually recognizing the extreme importance of energy security, and will pay unprecedented attention to energy production and consumption. The revolution and industrialization of new energy technology will be highly valued, accelerating the development of new energy technology [4].

Hydrogen energy, as a renewable, clean, efficient secondary new energy [5], has many advantages such as rich sources, high calorific value, clean and no pollution, various forms and energy as an energy storage medium [6]. Therefore, it is an important energy source for the energy transition and achieving carbon neutrality. As the world is facing increasing pressure from climate change and natural disasters, hydrogen energy has attracted much attention and become a strategic choice for many countries in the energy transition [7]. Hydrogen energy technology is becoming increasingly mature, and gradually industrialized.

More than 20 countries or alliances around the world have released or formulated the national hydrogen energy strategy [8]. The United States, which has long advocated the unique position and advantages of hydrogen in the future energy system, has occupied the market space in the hydrogen energy industry chain and dominated the [9] in each technical link. The European Union has passed early clean energy legislation to support the development of hydrogen energy and fuel cells. As early as 2017, the Japanese government put forward the strategy of "building a hydrogen society ahead of other countries", and released the "Basic Strategy for Hydrogen Energy" [10]. In 2020, the South Korean government's "Hydrogen Economy Roadmap 2040" and "Korean New Deal" specifically proposed the development path of hydrogen energy strategy [11]. It can be seen that all countries in the world have put forward high goals for the development of hydrogen energy to increase the international influence and discourse power. At present, the developed countries have been in the forefront of the world [12]. The development of hydrogen energy in China started late. In 2020, China will include hydrogen energy in the "14th Five-Year Plan" and the 14th-year vision, helping to achieve the strategic goal of "carbon peak and carbon neutral" [13]. According to the Medium-and Long-term Plan for the Development of Hydrogen Energy Industry (2021-2035), China's strategic positioning of hydrogen energy is as follows: hydrogen energy is an important part of the national energy system in the future, hydrogen energy is an important carrier for the green and low-carbon transformation of energy terminals, and hydrogen energy industry is a strategic emerging industry and a key development direction of the future industry [14].

Hydrogen can be produced in large quantities under industrial conditions or directly obtained from nature, which can be abundant and secondary preparation. One method is through the steam reforming process is a promoted hydrogen production method. The other is that most biomass, such as wood chips and agricultural and municipal waste, contains a lot of hydrogen. The second is to produce hydrogen through hydroelectrolysis, which can also be used to use solar thermochemical water decomposition using solar energy to decompose water into hydrogen and oxygen, and the resulting hydrogen purity of 99%. Finally, hydrogen can be obtained under photosynthesis through microorganisms such as cyanobacteria or green algae, purple or dark non-sulfur fermenting bacteria. This biological process requires only a relatively small amount of energy, produces no harmful emissions, and uses cheap and abundant raw materials. So the hydrogen can be widely obtained and prepared.

At the same time, hydrogen is stored in various ways, and the hydrogen produced in the field in the form of compressed gas, low temperature liquid or solid medium is widely used. However, existing gas pipelines can also be slightly modified to accommodate the effects of hydrogen embrittlement, such as the use of austenitic steel pipes, or the working pipeline network that transport hydrogen to residential and industrial areas for heating. Hydrogen can also be stored in large quantities in underground caves, salt mounds, and depleted oil and gas fields.

The application of hydrogen energy includes two ways: one is as the substitute of fossil fuel directly burned in the internal combustion engine, but due to the limitation of early combustion and tempering, the hydrogen mixing ratio of the fuel cannot be too high, resulting in the economic ratio of hydrogen fuel is not high; the other is as the redox reaction in the electrolyte to produce water [15]. As an advanced electrochemical device [16], the fuel cell can directly convert the hydrogen energy with high calorific value and environmental protection characteristics into electric energy. Hydrogen can be fed directly into the fuel cell structure to power energy-consuming units, without greenhouse gas emissions or direct combustion. Due to the outstanding advantages of high energy conversion efficiency, high energy density and zero emission, hydrogen fuel cell can be widely used in automobile power [17], distributed power station [18], residential electricity [19,20] and other fields.

The history of fuel cells began in 1838, when British scientist William Robert Grove explored a gas chamber using water decomposition to generate electricity and discovered [21]. In 1889, the term "fuel cell" was created by industrialist Ludwig Mond, who made an important discovery that the electrochemical oxidation of [22], unlike the oxidation of hydrogen in air combustion, is a thermodynamically more efficient energy release process. British scientist Francis Thomas Bacon assembled and tested the first fuel cell [23] in 1939. By 1990, the world gradually recognized the adverse effects of energy crisis and environmental pollution on human society, and had turned to the need to reduce the emissions of fossil fuels such as burning coal by [24], and the combustion efficiency of electrochemical power generation in fuel cells was significantly higher than that of traditional fossil fuels. Therefore, especially in the transportation industry, hydrogen fuel cell has gradually become a focus of research. Fuel cell electric vehicles will have the potential for [25], one of the new technologies leading the technological advances in the 21st century.

However, as domestic and foreign major auto brands increasingly announced plans to ban the sale of fuel cars, between 2025 and 2035, such as Mercedes-Benz, BMW, Volkswagen, Honda, Changan, BYD and other well-known car brands. Cars powered by new energy are increasingly promoted in the research and development of various countries. It is expected that in [26] 2025, the proportion of clean energy used in new and replaced vehicles in public services and social operation fields will reach 100%. And China's Hainan province has also set an example by announcing a ban on the sale of fuel cars across the island by 2030. In recent years, China's car ownership still maintains a growth trend. According to the statistics of the Ministry of Public Security, by the end of 2022, the number of motor vehicles in China reached 417 million, among which the number of new energy vehicles reached 13.1 million, accounting for 4.1% of the total vehicles, with a growth rate of 81.48% compared with 2021 [27]. As an important branch of new energy vehicles, fuel cell vehicles have the advantages of high efficiency, clean and zero pollution, and have gradually become a research hotspot in the industry [28]. In 2022, the production and sales of fuel cell vehicles in China reached 3,626 and 3,367 units respectively, compared with the same period, the production and sales were 2.04 times and 2.12 times of the previous period. The production and sales of fuel cell vehicles showed an explosive growth. However, there is still a huge gap between China's fuel cell technology and developed countries, so the research and development of key components of fuel cell is the path that we must adhere to. In conclusion, although hydrogen fuel cell technology has the advantages of high specific energy materials, the biggest challenge facing hydrogen fuel cell technology due to its low energy density, safety, short service life and higher cost to power hydrogen fuel cell vehicles is [29].

2. RESEARCH SIGNIFICANCE

As fuel cells are more and more put on the energy development agenda of various countries, in order to solve the shortcomings of fuel cells, we urgently need to solve the difficult problems existing in the commercialization of fuel cells. Compared with the commercialization of power batteries today, in addition to the country also needs to fund the development of fuel cells in policy and funds, we also need to better and faster realize the localization of core components of fuel cells, and reach the international leading level [30].

The application of fuel cell in the automotive field is more urgent to solve the problem of insufficient power density. In the high power and low voltage area, it is more likely to be affected by the concentration polarization. The improvement of the concentration polarization can improve the power density of the fuel cell through the change of the bipolar plate structure. In the actual operation of fuel cells, because the anode is pure hydrogen, and the cathode into the air, but the molar mass of air is larger than the air, oxygen diffusion rate is slower than hydrogen, so in the impact of the cathode concentration polarization than the anode more serious, so for the concentration of the cathode plate polarization study is more important [31].

In addition to solving the impact of insufficient power density, the high cost and relatively short life of hydrogen fuel cell vehicles are also urgent problems to be solved in the process of fuel cell commercialization. The flow field structure design determines whether the reaction gas is evenly distributed inside the battery, and the ability to generate water and residual waste gas can be discharged smoothly. The uneven distribution of reaction gas in the flow field will lead to local starvation, which may lead to the decline of fuel single cell performance and the reversal of positive and negative electrodes, which will affect the battery durability in serious cases. Therefore, it is necessary to design and analyze the bipolar plates that can effectively balance the power generation performance and reaction gas uniformity of fuel cells [32].

Although the parallel flow field covers the entire surface by distributing the gas into the parallel flow channel, it has the advantages of short process flow rate, reduced pressure, and low auxiliary power consumption. However, the traditional parallel flow field still exists the problem of gas concentration and liquid water is uneven distribution, accelerated the component aging and lead to serious flooding phenomenon, leading to the fuel cell power generation performance is poor, so for the traditional parallel flow field reaction gas distribution nonuniformity and the balance between power generation performance research is very important. This will help promote the development of hydrogen fuel cells toward a more compact, higher energy density, better safety performance and economic performance, and have more considerable social, ecological and economic benefits for China's energy structure transformation and the mitigation of global warming and environmental pollution [33].

3 HYDROGEN FUEL CELL BIPOLAR PLATE AT HOME AND ABROAD

Fuel cell vehicles (Fuel Cell Electric Vehicles, FCEVs) is a kind of new energy vehicles mainly driven by fuel cell engines as the power system. Compared with traditional fuel or gas vehicles, they do not need complex mechanical reciprocating motion device, and the structure is relatively simple. Fuel cell vehicles mainly include fuel cell engine system, motor system, auxiliary power supply system, on-board hydrogen supply system, vehicle control system and other mechanical and electronic structure composition of [34]. Among them, the fuel cell engine system, as the key component system, provides the main power for the fuel cell vehicle, and is the "heart" of the fuel cell vehicle.

3.1 Research Status of Hydrogen Fuel Cell Bipolar Plate at Home and Abroad

Bipolar plates, also known as flow field plates, account for more than 60% of the weight of the fuel cell stack and more than 30% of the total cost of [35]. In the study of bipolar plate flow field configuration, the traditional flow field, and the traditional flow field includes the parallel flow field and the 3D flow field, in addition, the mixture of flow field to improve the power density of the battery and improve the distribution of reactants.

In the conventional flow field,as shown in Fig. 1 (a), the reactive gas in the serpentine flow field flows through a single winding flow channel to the outlet, also known as a single serpentine flow field. The snake flow field only passes through a single snake flow channel [36], so the flow rate in the flow channel is relatively high, which has excellent drainage performance, and can quickly blow away the concentrated liquid water. However, when the flow field area increases, the pressure drop will increase greatly; if there is any blockage in the snake flow channel, the whole flow field will be completely ineffective.

The structure design of parallel flow field is relatively simple, generally composed of several parallel DC channels. As shown in Fig. 1 (b). The distance between the inlet to the outlet of each flow channel is shorter compared to other traditional flow fields, so the pressure drop is small. However, when the area of the designed

DC flow field increases, the number of DC channels increases with the increase of width, which will lead to the poor uniformity of reaction gas distribution between different DC channels. At the same time, the flow rate in the parallel flow field increases with the width of the flow channel, and the flow rate gradually decreases, resulting in the water of the reaction product in the flow channel is not easy to be blown away, which leads to the aggregation of liquid water, reducing the reaction efficiency and working life.

The cross-finger flow field is a non-circulation flow field structure. As shown in Fig. 1 (c). There are many blocked channels in multiple channels, aiming to strengthen the forced convection between the reactive gas and the porous electrode in the channel to achieve high power generation performance. However, the existence of many blocked flow channels will increase the increase of the pressure drop in the flow field, leading to the blockage of the water in the flow field.

A grid-like flow field is a structure of upper and down flow channel. As shown in Fig. 1 (d). Compared with the parallel flow field, the power generation performance is better, but compared with the snake flow field, [37] between the two. The drainage capacity of the grid flow field is inferior to that of the parallel flow field, and the performance of the grid flow field is different in the area of medium and high current density.

For the parallel flow fields, the researchers conducted a series of related studies. Liu et al. [38] proposed a fuel cell based on the parallel flow field micro distributor, which improves the output power density by increasing the flow field pressure drop to fully enhance the flow uniformity. Using theoretical analysis and numerical simulation, the parallel flow field with a micro dispenser is systematically studied. We show that the maximum power density increases nonlinearly as the microdispenser size decreases. When the microchannel of length 0.2mm is better than the conventional parallel flow field in terms of gas concentration distribution, gas velocity distribution and current density, the maximum power density of the improved fuel cell flow field is 22.8% higher than that of the conventional parallel flow field, and only 10.3% lower than that of the serpentine flow cell. At the same time, the pressure drop of the optimized flow site is about two orders of magnitude lower than that of the serpentine flow field, which is an optimal scheme to replace the serpentine flow field. Moreover, for PEMFC with parallel flow fields, the uneven distribution of oxygen concentration in the GDL / CL interface can be alleviated by increasing the pressure drop between the main inlet and outlet channels.

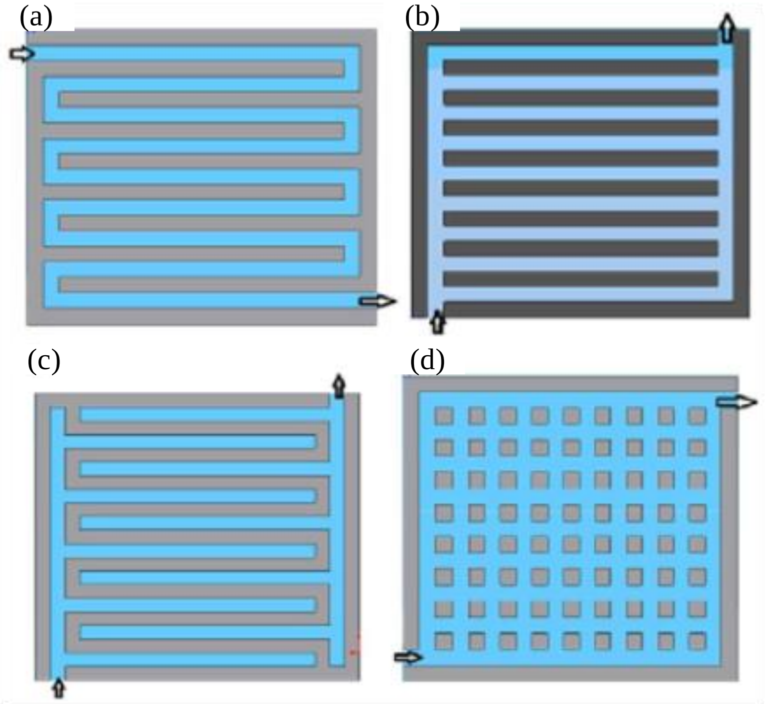

Fig. 1. Schematic diagram of common flow field forms

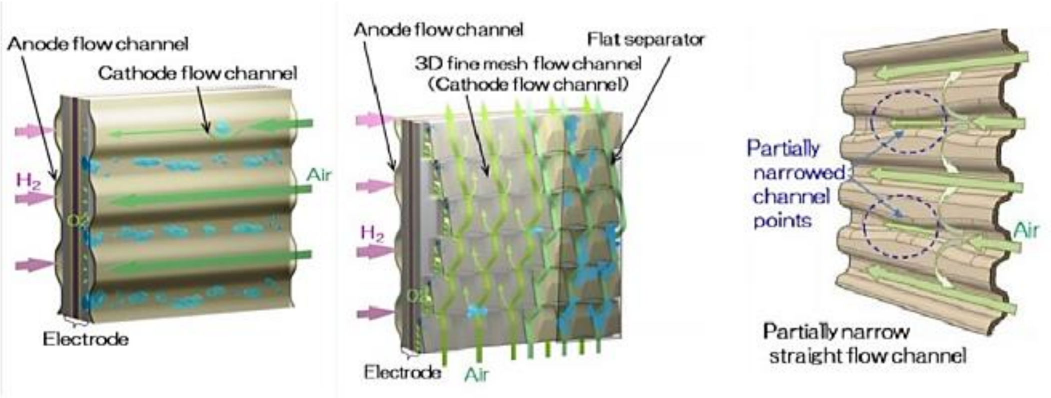

Fig. 2. Flow field design of Toyota Mirai fuel cell

In view of the problems of uneven reaction gas and serious flooding in the parallel flow field, Chen Yao [39,40,41] et al. respectively proposed three schemes to optimize the parallel flow field. The stepped parallel flow field than the traditional parallel flow field power density increased 22.4%, zigzag parallel flow field power density than parallel flow field increased 34.9%, gradient wavy flow field increased by 28.9% than before, zigzag parallel flow field in three optimal, three schemes are effectively increased the speed of cathode gas flow, makes the reaction gas uniform distribution, accelerate the generation of water discharge, inhibit the flooding phenomenon.

Some scholars have investigated the effects of cathodic hypoxia on PEMFC. Qu et al [42] found that air deprivation diluted the concentration of reactants in the downstream part of the fuel cell flow channel, resulting in a decline in local performance, which in turn leads to concentration polarization and decreased overall battery output performance. Aniguchi et al. [43] studied the effect of cathode air shortage on MEA through experiments, and found that when the fuel cell operates at low air velocity, it would reduce the effective surface area of the platinum on the cathode side of the membrane electrode, and aggravate the damage with the operation of the battery, permanently reducing the catalytic efficiency and performance of PEMFC. Liu et al. [44] investigated the effect of air shortage on PEMFC performance by combining experiments with CFD simulations. The results all suggest that the lack of reactants can have a significant impact on battery performance and may even lead to safety concerns.

Some scholars have also noticed the effect of changing the flow field structure on the water distribution of the fuel single cell. Yuan et al. [45] studied the water distribution of different structures of the fuel cell and used numerical simulation to simulate the water distribution of each fuel cell structure in the single channel. They concluded that the area with the highest water content is GDL, accounting for 51%, followed by the flow field channel, about 40%; followed by proton exchange membrane and catalyst layer. The maximum water content at the voltage of 0.5V is 72.6mm3。

We inspired the flow field design of the bipolar plate As shown in the picture1-2. Tomoo Yoshizumi et al. [46] On the basis of the first generation 3D flow field of MI RAI, the cross section of the parallel flow field to the direct channel. The results show that the oxygen concentration in the GDL increases by 130% compared with the traditional DC channel, which is the same level as the first generation 3D channel of MIRAI, and the mass power density increases from 2.8kW / kg to 5.4 kW / kg. Compared with the previous generation of fuel cell stack, the power generation performance, stability and life are significantly improved, and the cost is also reduced.

Based on the traditional flow field, the bionic flow field is derived. Compared with the traditional flow field, the bionic flow field can reduce the pressure drop to a very small extent,reduced flooding phenomenon. Iranzo et al. [47] illustrate the difference of different bionic flow field structures based on natural and biological structures, which showed that the bionic flow field has more efficient water management and higher monomer voltage compared with the conventional flow field. At the same time, the pressure drop of the blade and lobe type flow field (26~27Pa) is reduced compared with the traditional flow field (38~41Pa), which reduces the pumping power and is conducive to the electrochemical reaction of the fuel cell. Although this biomimetic design has been successful so far and has been widely used in the bipolar plate flow field design, it is widely believed that the biomimetic design has not yet reached its full potential.

The [48] has studied the influence of maize leaf vein sieve plate structure on the performance of fuel cells. The results show that the opening rate, the number of holes, the rotation Angle of the sieve holes and the number of sieve plates all have an impact on the improvement of battery performance. The best optimized sieve plate structure scheme is: when the opening rate is 22.3%, the number of screening holes is 4, the screening hole arrangement rotation is 25%, the number of sieve plates is 5, the power generation performance of the screening plate is improved by 5.1% compared with that of the parallel flow channel, and the power density is 0.97W. By comparing the polarization curve, power density curve, speed field distribution, reactant distribution and output net power and other characteristic parameters, it is found that the power generation performance of fuel cell at this time is optimal.

Therefore, in addition to the impact of the performance of the flow field structure of the bipolar cell, we should not only pay attention to the change of the reaction gas, but also refer to the change of the distribution of water, to improve the gas shortage and flooding of the cathode.

3.2 Research Status of Domestic and Foreign Bipolar Plates with Convex Platform, Sub-Flow Channel or Depression Structure in the Flow Field

The baffle-specific design enhances PEMFC performance. Guo et al. [49] made a numerical comparison between the mass transfer of PEMFC and the battery performance under different baffle channels. The results showed that the rectangular baffle enhanced the most to the reactant transfer and the battery performance, but the power loss in the rectangular baffle channel was also the highest. Zhang et al. [50] proposed single-channel PEMFC with wedge fins in the cathode channel and numerically examined the effects of fin parameters, such as volume, number and porosity of GDL. Wedge fins were found to effectively improve PEMFC performance. As the volume of the fin increases, the oxygen mass fraction in the outlet area of the cathode channel was low. The effect of [51] on parallel flow fields and staggered blocking configurations is numerically studied by Heidary et al. The results show that the staggered configuration increases the maximum net power by 11% and by 7% compared to the baseline case. It reduces the pressure drop by 70%. Jang et al. [52] used numerical simulation to design the baffle into the fuel cell channel and optimize the baffle position to obtain the maximum average current density by combining the simplified conjugate gradient method and commercial CFD code.

Based on the parallel flow field, Liao et al. [53] proposed a zigzag flow field with opposite anode / cathode arrangement to reduce the mass transfer resistance and provide more uniform oxygen, water content, temperature and current density distribution. The simultaneous addition of obstacles to the channel can effectively enhance the transfer of reactants to GDL to obtain better electrochemical reactions and a wider range of working current density.

Reasonable flow field structure can improve the performance of fuel cells and fuel utilization rate. Meng Qingran et al. [54] analyzed the velocity vector, the pressure distribution in the flow channel and the distribution of cathodic oxygen content by establishing the new flow field structure. The results show that the number of rectangular grooves in the flow of the flow channel. SuA and [55] designed stepped channels applied to parallel and snake flow fields, respectively. The results show that the stepped flow field has obvious influence on the parallel flow field, but not on the mass transfer performance of the snake flow field.

Yulin Wang et al. [56] proposed a novel GDL with array grooves to further facilitate mass transfer and drainage of PEM fuel cells. By applying a three-dimensional multiphase fuel cell model, the effects of the groove size and number, the GDL length with the array grooves and the uneven distribution of the array grooves on the transmission of internal physical quantities and battery performance are investigated. It aims to obtain a reasonably newly designed GDL with array grooves to achieve improved mass transfer and drainage, thereby improving the performance of fuel cells. When the distance of the unevenly distributed interval array groove decreases, it facilitates the current density uniformity and the overall battery performance. The new GDL has a non-uniform array slot length of 3mm, 15mm width and 1mm length, showing the highest performance of the fuel cell and a maximum power density of about 3.5% higher than the conventional GDL. In addition, the current density distribution near the outlet is enhanced, which facilitates the operation stability and life of the fuel cell.

In his paper, Shen Jun [57] used numerical simulation and experimental methods to study the effect of adding platform in the single DC channel of fuel cell on cell performance. The results show that the enhancement of gas mass transmission and the rectangular convex platform is better than the semicircular convex platform. With the larger number of convex platform, the improvement of fuel cell performance, with the effect on battery performance. Perng S W et al. [58] established a 3D (3 D) numerical simulation to study the effect of the trapezoidal baffle on the net power of PEMFC. The geometric parameters of the trapezoidal baffle used in the channel include the angle and the height. The results showed that the maximum enhancement of PEMFC was achieved by the trapezoidal block with an angle of 60° and a height of 1.125mm. Du Qing [59] et al. of Tianjin University invented a cathode current field plate of proton exchange membrane fuel cell staggered in parallel partition, with porous electrodes set between the cathode current field plate and the anode current field plate. Taking the horizontal line of the cathode parallel flow field plate as the reference, there are provided with the baffle area and the baffle area. The baffle staggered area is divided into n even areas, and each area is provided with M row N column baffle, and the gas forms the pressure difference in the adjacent area in the flow channel of the cathode parallel flow field. The pressure difference promotes gas flow in high and low pressure areas to enhance the mass transfer and water removal capacity of the cathode flow field plate, and the strength of subridge convection can be changed by the number of baffle. The ridge structure ensures the mechanical support and low resistance of the fuel cell, forming the three-dimensional flow of gas, and then improving the net power and battery output performance of the fuel cell. On the basis of improving the water removal capacity, the oxygen concentration in the porous electrode can be effectively increased to avoid local oxygen deficiency. It is also proposed in the invention that the strength of the underridge convection can be changed by changing the number of partitions in the baffle area, or by directly changing the number, shape or interval of the baffle in the flow field to enhance the gas transmission in the direction of the porous electrode.

Farzin Ramin et al [60] proposed a trap-type single-pass flow field. Through numerical simulation, the following conclusion is obtained: compared with the traditional parallel flow field, the diffusion rate of the trap-type channel oxygen to the cathode electrode is much higher, which improves the distribution of oxygen and water in the cathode flow field, and improves the power generation performance of the fuel cell. The paper of the influence of trap length and number on the power generation performance of fuel cells is also studied. When the trap length gradually increases to 8mm, the power density is the highest at the critical value, and the continuous increase of the trap length will play a negative effect on the improvement of the fuel cell. When studying the effect of the number of traps on the DC channel, when the power generation performance of fuel cells when the number of traps is 2, but the number of traps is greatly reduced.

4. CONCLUSION AND OUTLOOK

The document provides a detailed introduction to the current development status of flow field design for bipolar plates in hydrogen fuel cells, with a focus on analyzing the impact of traditional and new flow field designs on fuel cell performance. Through numerical simulation and experimental verification, researchers have optimized traditional flow fields such as parallel flow fields, serpentine flow fields, and interdigital flow fields, and explored innovative designs such as biomimetic flow fields and 3D flow fields. At the same time, the effect of adding protrusions, sub channels, or groove structures in the flow channel on improving the performance of fuel cells was also studied. In addition, the article also explores the role of specific designs of baffles, platforms, or slot structures in enhancing the performance of PEMFC, as well as the specific effects of these designs under different parameters. Overall, this document comprehensively summarizes the research achievements and development trends in the field design of bipolar plates for hydrogen fuel cells at home and abroad. Provided important support for subsequent related researchers. Future research should focus on improving the performance of fuel cells, reducing costs, and enhancing their widespread applications. By continuously optimizing design and material selection, fuel cell technology is expected to play a greater role in energy conversion and storage, contributing to achieving carbon peak and carbon neutrality goals.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Eberle U, Müller B, Von Helmolt R. Fuel cell electric vehicles and hydrogen infrastructure: status 2012[J].Energy & Environmental Science. 2012;5(10):8780-8798.
2. Huang Huiping, Zhao Rongqin, Han Yuping. Research on implied carbon emission flow in different regions of China [J]. Journal of North China University of Water Resources and Water Power (Natural Science Edition). 2019;40(4):83-93.
3. Li Li, Lei Yalin, Wu San busy, etc. Research on greenhouse gases and air pollution emission produced by coal consumption in China [J]. Journal of North China University of Water Resources and Electric Power (Natural Science Edition). 2021;42(6):81-85.
4. Trahey L, Brushett FR, Balsara NP, et al. Energy storage emerging: A perspective from the Joint Center for Energy Storage Research[J]. Proceedings of the National Academy of Sciences. 2020;117(23): 12550-12557.
5. Huang Sheng, Wang Jingyu, Guo Pei, et al. Short-term strategy and long-term outlook for energy structure optimization under the carbon neutral target [J]. Chemical Progress. 2022;41(11):5695-5708.
6. Zou C, Li J, Zhang X, et al. Industrial status, technological progress, challenges, and prospects of hydrogen energy[J]. Natural Gas Industry B; 2022.
7. Bricout A, Slade R, Staffell I, et al. From the geopolitics of oil and gas to the geopolitics of the energy transition: Is there a role for European supermajors? [J].Energy Research & Social Science. 2022;88:102634.
8. Arat HT, Baltacioglu MK, Tanç B, et al. A perspective on hydrogen energy research, development and innovation activities in Turkey[J].International Journal of Energy Research. 2020;44(2):588-593.
9. Glenn JC, Gordon TJ. The Millennium Project: Challenges We Face at the Millennium[J].Technological Forecasting and Social Change. 2001;66(2-3):129-312.
10. Zhang Can, Zhang Mingzhen. Hydrogen energy industry standardization system: Comparison and enlightenment between China and abroad [J]. Science and Technology Herald. 2022;40(24):38-49.
11. Rana Danish Nisar. A study on assessing the implications of india-united states strategic partnership on pakistan's security post-2004: From Pakistan's Perspective [D]. Wuhan: Central China Normal University; 2021.
12. Zou CAI, Li Jianming, Zhang Qian, etc. Current situation, technological progress, challenges and prospects of hydrogen energy industry [J]. Natural gas Industry. 2022;42(4):1-20.
13. Notice of Shenzhen Municipal People's Government on Printing and Distributing the 14th Five-Year Plan for National Economic and Social Development and the Outline of Shenzhen-Shantou Special Cooperation Zone [J]. Bulletin of Shenzhen Municipal People's Government, 2022 (13): 4-49.
14. Liu Xiaoqi, Chen Yao, Zhou You, etc. Large-scale electro-hydrogen coupling

system: Technology perspective analysis and prospect of Large Energy Enterprises in China and Europe [J]. Chinese Journal of Electrical Engineering. 2023;1-7.

15. Abdelkareem MA, Elsaid K, Wilberforce T, et al. Environmental aspects of fuel cells: A review[J]. Science of The Total Environment. 2021;752:141803.
16. Huang HZ, Liu MX, Li X, et al. Numerical simulation and visualization study of a new tapered-slope serpentine flow field in proton exchange membrane fuel cell [J], Energy. 2022;246.
17. Pramuanjaroenkij A, Kakaç S.The fuel cell electric vehicles: The highlight review[J].International Journal of Hydrogen Energy; 2022.
18. Jo A, Oh K, Lee J, et al. Modeling and analysis of a 5 kW eHT-PEMFC system for residential heat and power generation[J].International Journal of Hydrogen Energy. 2017;42(3):1698-1714.
19. Wu W, Zhai C, Sui Y, et al.A novel distributed energy system using high-temperature proton exchange membrane fuel cell integrated with hybrid-energy heat pump [J]. Energy Conversion and Management. 2021;235:113990.
20. Xing L, Xiang W, Zhu R, et al.Modeling and thermal management of proton exchange membrane fuel cell for fuel cell/battery hybrid automotive vehicle [J]. International Journal of Hydrogen Energy. 2022;47(3):1888-1900.
21. Morus IR, William Robert Grove. Victorian Gentleman of Science [M]. University of Wales Press; 2017.
22. Mond L, Langer C. Proceedings of the royal society of London [J].1889;46:296-304.
23. Bacon FT, Fry TM. Review lecture-the development and practical application of fuel cells[J]. Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences. 1973;334(1599):427-452.
24. Morus IR. William Robert Grove. Victorian gentleman of science [M]. The United Kingdom of Great Britain and Northern Ireland : University of Wales Press; 2017.
25. Edwards PP, Kuznetsov VL, David WIF, et al. Hydrogen and fuel cells: Towards a sustainable energy future [J]. Energy Policy. 2008;36(12):4356-4362.
26. Tangdian Wide. Research on the development strategy of Haikou WZ Company under the background of "Clean Energy Island" [D]. Haikou: Hainan University; 2022.
27. Zhang Hong. In 2022, the number of motor vehicles in China reached 417 million [N]. People's Public Security Daily · Traffic Safety Weekly. 2023-01-13 (001).
28. Liu Yunong, Xu Zhan, Ni Zhonghua, etc. Study on the prediction and influencing factors of on-board deep-cooling and high-pressure hydrogen storage process [J]. Journal of Mechanical Engineering.2021;57(6):52-59.
29. Zhang Kejian. Research on the energy management strategy of fuel cell vehicle hybrid power system [D]. Changchun: Jilin University; 2022.
30. Liu Shouyi. Preparation Mechanism and Experimental Study of Cathode Gas Diffusion Layer for Proton Exchange Membrane Fuel Cell [D]. Qingdao University of Science and Technology; 2021.
DOI: 10.27264/d.cnki.gqdhc.2021.000310
31. Huang Wenwen. Simulation analysis and optimization research on proton exchange membrane fuel cell based on novel flow field design [D]. Beijing University of Chemical Technology; 2024.
DOI: 10.26939/d.cnki.gbhgu.2024.001870
32. Peng Suping. development strategy and future prospects of hydrogen energy and fuel cells in China [J]. China Industry and Information Technology. 2023;(4): 36-41.
DOI: 10.19609/j.cnki.cn10-1299/f.2023.04.013
33. Zheng Deli. Design and research of biomimetic sinusoidal bipolar plate flow field with interactive channels [D]. Jilin University; 2024.
DOI: 10.27162/d.cnki.gjlin.2024.001538
34. Xin Weiwei. Research on power system simulation and energy management strategy of fuel cell commercial vehicles [D]. Guilin: Guilin University of Electronic Technology; 2021.
35. Li X, Sabir I.Review of bipolar plates in PEM fuel cells: Flow-field designs[J].International journal of hydrogen energy. 2005;30(4):359-371.
36. Jiao Kui, Wang Bowen, Du Qing, etc. Hydrothermal management of proton exchange membrane fuel cells [M]. Beijing: Science Press; 2020.
37. Wang Yibo. Simulation analysis of water management of proton exchange membrane fuel cell [D]. Zhengzhou: North

China University of Water Resources and Hydropower Power; 2020.

38. Liu H, Yang W, Tan J, et al.Numerical analysis of parallel flow fields improved by micro-distributor in proton exchange membrane fuel cells [J]. Energy Conversion and Management, 2018;176:99-109.
39. Chen X, Yu Z, Wang X, et al.Influence of wave parallel flow field design on the performance of PEMFC[J].Journal of Energy Engineering. 2021;147(1):04020080.
40. Chen X, Yu Z, Yang C, et al.Performance investigation on a novel 3D wave flow channel design for PEMFC[J].International Journal of Hydrogen Energy. 2021;46(19):11127-11139.
41. Chen Yao. Design of fuel cell bipolar plate for enhanced mass transfer [D]. Yueyang: Hunan University of Science and Technology; 2021.
42. Qu S, Li X, Hou M, et al. The effect of air stoichiometry change on the dynamic behavior of a proton exchange membrane fuel cell[J].Journal of Power Sources. 2008;185(1):302-310.
43. Taniguchi A, Akita T, Yasuda K, et al.Analysis of degradation in PEMFC caused by cell reversal during air starvation[J].International Journal of Hydrogen Energy. 2008;33(9):2323-2329.
44. Liu Z, Yang L, Mao Z, et al.Behavior of PEMFC in starvation[J].Journal of power sources. 2006;157(1):166-176.
45. Yuan Wei, Li Jie, Xia Zhongxian, et al.Study of water transport mechanism based on the single straight channel of proton exchange membrane fuel cell [J]. AIP Advances. 2020;10(10).
46. Yoshizumi T, Kubo H, Okumura M. Development of high-performance fc stack for the new MIRAI, SAE Technical Paper 2021-01-0740; 2021.
47. Iranzo A, Arredondo CH, Kannan AM, et al. Biomimetic flow fields for proton exchange membrane fuel cells A review of design [J]; 2019.
48. Jazai. Design and study of PEMFC bipolar plate flow channel based on maize leaf sieve structure [D]. Changchun: Jilin University; 2022.
49. Guo H, Chen H, et al. Baffle shape effects on mass transfer and power loss of proton exchange membrane fuel cells with different baffled flow channels [J]. International Journal of Energy Research. 2019;43(7):2737-2755.
50. Zhang S, Qu Z, Xu H, et al.A numerical study on the performance of PEMFC with wedge-shaped fins in the cathode channel[J].International Journal of Hydrogen Energy. 2021;46(54):27700-27708.
51. Heidary H, Kermani MJ, Prasad AK, et al. Numerical modelling of in-line and staggered blockages in parallel flowfield channels of PEM fuel cells[J]. International Journal of Hydrogen Energy. 2017;42(4):2265-2277.
52. Jang JY, Cheng CH, Huang YX. Optimal design of baffles locations with interdigitated flow channels of a centimeter-scale proton exchange membrane fuel cell[J]. International Journal of Heat and Mass Transfer. 2010;53(4):732-743.
53. Liao Z, Wei L, Dafalla AM, et al. Analysis of the impact of flow field arrangement on the performance of PEMFC with zigzag-shaped channels[J]. International Journal of Heat and Mass Transfer. 2021;181:121900.
54. Meng Qingran, Chen Hailun, Tian Aihua, etc. Effect of flow field trench on the performance of proton exchange membrane fuel cells [J]. Power Supply Technology. 2021;45(1):22-26.
55. Su A, Weng FB, Chi PH, et al. Effect of channel step-depth on the performance of proton exchange membrane fuel cells[J]. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy. 2007;221(5):617-625.
56. Wang Y, Zhang P, Gao Y, et al.Optimal design of cathode gas diffusion layer with arrayed grooves for performance enhancement of a PEM fuel cell [J]. Renewable Energy. 2022;199:697-709.
57. Shen Jun. Research on flow field optimization and hydrothermal management of fuel cell based on enhanced mass transfer [D]. Wuhan: Huazhong University of Science and Technology; 2018.
58. Perng SW, Wu HW. A three-dimensional numerical investigation of trapezoid baffles effect on non-isothermal reactant transport and cell net power in a PEMFC [J]. Applied Energy. 2015;143:81-95.
59. Tianjin University. The cathode current field plate of a proton exchange membrane

fuel cell [P]. China: CN202110473047; 2021-07-30.

60. Ramin F, Sadeghifar H, Torkavannejad A. Flow field plates with trap-shape channels to enhance power density of polymer electrolyte membrane fuel cells [J]. International Journal of Heat and Mass Transfer. 2019;129:1151-1160.

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