

Fuel Cell Electric Vehicle Technology

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ABSTRACT

Nowadays, the level of science and technology is developing rapidly, and there are more and more ways for people to choose to travel. Under the environment of people's increasing pursuit of environmental protection and sustainable development, the development of the electric vehicle industry has attracted much attention, which contains fuel cell electric vehicles. Fuel cell electric vehicles, as one of the many types of electric vehicles, are special in that chemical energy is converted into electrical energy through the reaction of hydrogen and oxygen, and then the electrical energy is converted into mechanical energy through the drive system. This paper describes the types of fuel cell electric vehicles, introduces the working principle and basic mechanism in detail, and explores the development prospects of the related industry and the basic problems faced by it through the study of its core technology, so as to provide some references for the development of new energy automobile related industries.

KEYWORDS

Electric Vehicle; Fuel Cell; New Energy.

1. INTRODUCTION

At present, the world's environmental pollution and resource constraints are becoming more and more serious, people are beginning to travel more and more in pursuit of environmental protection, so new energy vehicles have become the choice. Fuel Cell Electric Vehicle (FCE), as a kind of environmentally friendly, economical and efficient transportation, has attracted great attention from governments. Fuel Cell Electric Vehicle (FCEV) mainly refers to a kind of new energy vehicle using fuel cell as the driving force.[1] FCEV carries out a chemical reaction between hydrogen and oxygen inside the vehicle, and converts the chemical energy into electricity, and only water is produced in the process, which is more environmentally friendly than the traditional fuel vehicles. In addition, FCEVs rely on a number of internal battery packs for their drive, making them more efficient at converting energy than fuel cars, and are one of the most common types of electric vehicles today.

2. TYPES OF FUEL CELL ELECTRIC VEHICLES STRUCTURES AND PRINCIPLES OF OPERATION

2.1. Main Types of Fuel Cell Electric Vehicles

The main types of FCEVs can be classified into three categories, according to fuel characteristics, multiple power supply configurations, and fuel storage forms, which can also be categorized in more detail according to their respective characteristics. Table1 shows the main types of FCEVs in detail.

Table 1. Main types of FCEVs

Fuel Cell Electric Vehicles	kind
Fuel characteristics	Direct-fueled FCEVs
	Re-fueled FCEVs
Multiple power supply configurations	FCEVs powered by pure fuel cells
	FCEVs driven by fuel cells in combination with auxiliary batteries
	FCEV driven by fuel cell and supercapacitor combination
	FCEV driven by fuel cell in combination with auxiliary battery and supercapacitor
Fuel storage form	FCEV with compressed hydrogen fuel
	Liquid hydrogen fueled FCEVs
	FCEVs for alloy hydride hydrogen storage fuels

2.1.1. Classification According to Fuel Characteristics

FCEVs can be categorized into direct-fueled FCEVs and reformed-fueled FCEVs according to their fuel characteristics; direct-fueled FCEVs are mainly composed of pure hydrogen and methanol, with liquid hydrogen and compressed hydrogen being used to store hydrogen fuel. Reformulated FCEVs are composed of methanol, methane, natural gas, etc. The structure of reformed FCEVs is more complex because of the addition of a reformer.

2.1.2. Classification According to Multiple Power Supply Configurations

FCEVs can be categorized into four different types according to the different configurations of multiple power sources: pure fuel cell drive, auxiliary battery combined drive, fuel cell and supercapacitor combined drive, and fuel cell and auxiliary battery and supercapacitor combined drive. [2] Among the above types, the most widely used is the FCEV driven by fuel cell and auxiliary battery.

2.1.3. Classification According to the Form of Fuel Storage

According to the different fuel storage methods, the first is compressed hydrogen fuel FCEV, which preserves hydrogen by means of high-pressure hydrogen storage, the second is liquid hydrogen FCEV, which cools hydrogen to a liquid at a very low temperature to increase storage density, and the last is alloy hydride hydrogen storage FCEV, which stabilizes and stores hydrogen and alloy hydride, and then waits until it is needed to obtain the hydrogen by means of heating and so on. Of the above three methods, compressed hydrogen fuel technology is relatively mature.

2.2. Basic Structure of Fuel Cell Electric Vehicles

The basic structure of FCEV contains fuel cell, hydrogen storage tank, auxiliary power unit, DC/AC inverter and DC/DC converter, drive motor and controller.

2.2.1. Fuel Cells

Fuel cell is the main power source, the core of which is the fuel cell stack and contains components such as hydrogen supply system, oxygen supply system and chemical reaction processor. As a high-efficiency power generation device, the chemical energy of the fuel is converted into electrical energy by electrochemical reaction method without burning the fuel, which improves the efficiency of the fuel cell stack.

2.2.2. Hydrogen Storage Tanks

Hydrogen storage tanks are mainly used to store high-pressure hydrogen for use in fuel cells, affecting the safety and range of FCEVs.

2.2.3. Auxiliary Power Units

Auxiliary power unit also plays a very important role in FCEV, usually using the battery pack, supercapacitor and flywheel storage of one of the three options, but also can use the battery pack and supercapacitor, battery pack and flywheel storage to form a dual power supply.

2.2.4. DC/AC Inverters and DC/DC Converters

In order for an FCEV to run properly, the fuel cell usually needs to use a DC/AC inverter to transport power to the drive motor, or it can transport power to the motor by charging the battery via a DC/DC converter when the power needed to run the electric vehicle increases. Both of these methods can power the FCEV for normal driving.

2.2.5. Drive Motors

Drive motors are usually DC brushed motors, AC asynchronous motors, permanent magnet synchronous motors, and switched reluctance motors, etc.[3] convert the electrical energy generated by the fuel cell into mechanical energy, and thus drive the FCEV properly.

2.2.6. Controller

The controller is the control center of the FCEV, which mainly includes the fuel cell controller, auxiliary energy storage controller, and drive motor controller and is connected to each control module, and provides feedback on the real-time vehicle conditions by receiving the driver's demand information.

2.3. Working Principle of Fuel Cell Electric Vehicles

FCEVs use hydrogen as fuel to generate electrical energy to power a drive motor, which in turn powers the vehicle. [4]A fuel cell is essentially an electrochemical device, and the exploration of how FCEVs work is really about analyzing the basic reaction process of fuel cell power generation. Fuel cell consists of electrolyte, catalyst and cathode and anode similar to conventional batteries, and provides hydrogen at the anode and oxygen at the cathode. The anode is accelerated by the catalyst, the hydrogen gas is rapidly decomposed into hydrogen ions and electrons, the hydrogen ions enter the electrolyte placed between the two electrodes and move through the electrolyte to the cathode, when the electrons slowly flow from the external circuit to the cathode. The reaction on the cathode is divided into two stages, the first step, located in the molecule of the chemical bond between the oxygen atoms will be broken, the second step, the oxygen atoms in the external circuit absorbs the anode's electrons to make it negatively charged, by the influence of the catalyst, the oxygen and the positively charged hydrogen ions in the electrolyte and the negatively charged oxygen atoms on the anode, the reaction results in the production of water. Fuel cells can also work continuously without the continuous operation of ions in the electrolyte, this process will produce a large number of charges on the two electrodes, and then connect the external circuit will produce alternating current.

During the electrochemical reaction of a fuel cell, the electrolyte has selective passage; only protons generated at the anode can pass through the electrolyte, while hydrogen, the reactant at the anode, and electrons, the product, cannot pass through the electrolyte. Continuous generation of electricity from a fuel cell requires a constant input of hydrogen fuel and discharge of water as a reaction by-product. Figure1 shows in detail how a fuel cell works.

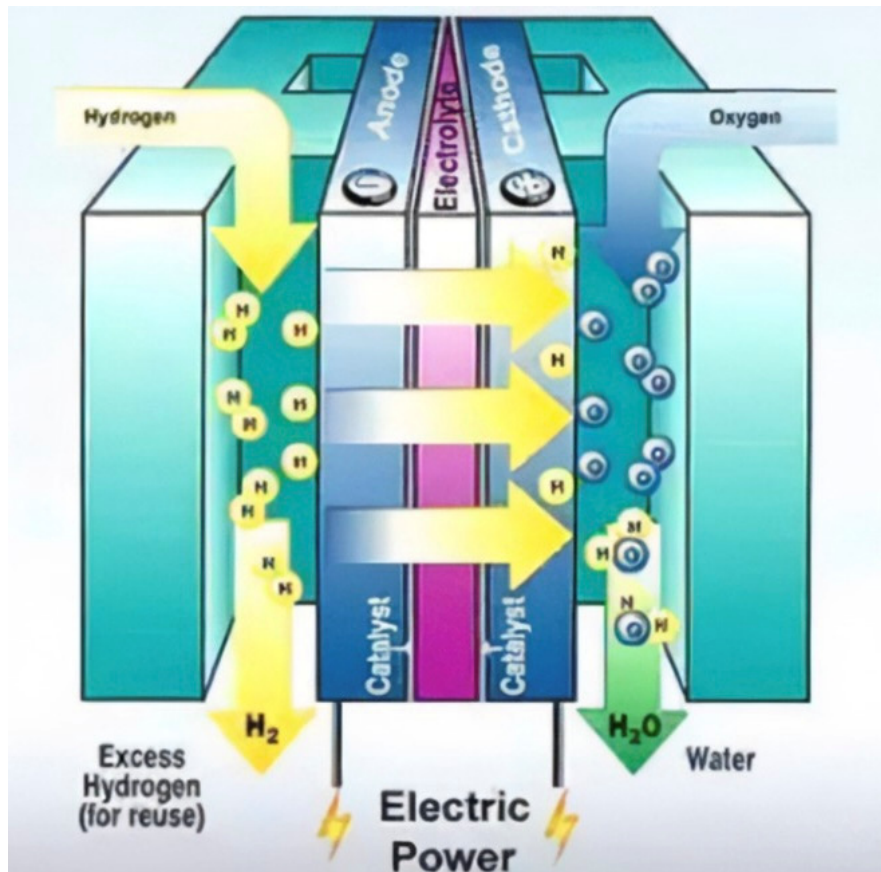


Figure 1. Principle of operation of a fuel cell

3. CORE TECHNOLOGIES FOR FUEL CELL ELECTRIC VEHICLES

FCEV is an integrated product of the latest achievements in new materials, new energy, computers, chemical power supply, automatic control, power electronics, current drag, automotive and other engineering technologies. [5]In the study of FCEV type structure and working principle at the same time, but also pay attention to the FCEV research and development process also contains many key technologies, the next we will analyze the key technologies of FCEV from five aspects.

3.1. Fuel Cell Technology

The power core of FCEV is fuel cell, so fuel cell technology plays an important role in many technologies of FCEV, and fuel cell technology includes the following aspects.

3.1.1. Membrane Electrode Module Technology

The proton exchange membrane, catalytic layer and gas diffusion layer together constitute the membrane electrode assembly. Among them, the proton exchange membrane, as the core component of the membrane electrode assembly, allows only protons to pass through and does not allow the flow of electrons and gases, which becomes the key to the performance of the fuel cell. Currently, most of them use perfluorosulfonic acid reinforced composite membranes, which have significant performance enhancement because of their lightweight and thinning characteristics. Figure2 shows the structure of the membrane electrode assembly in detail.

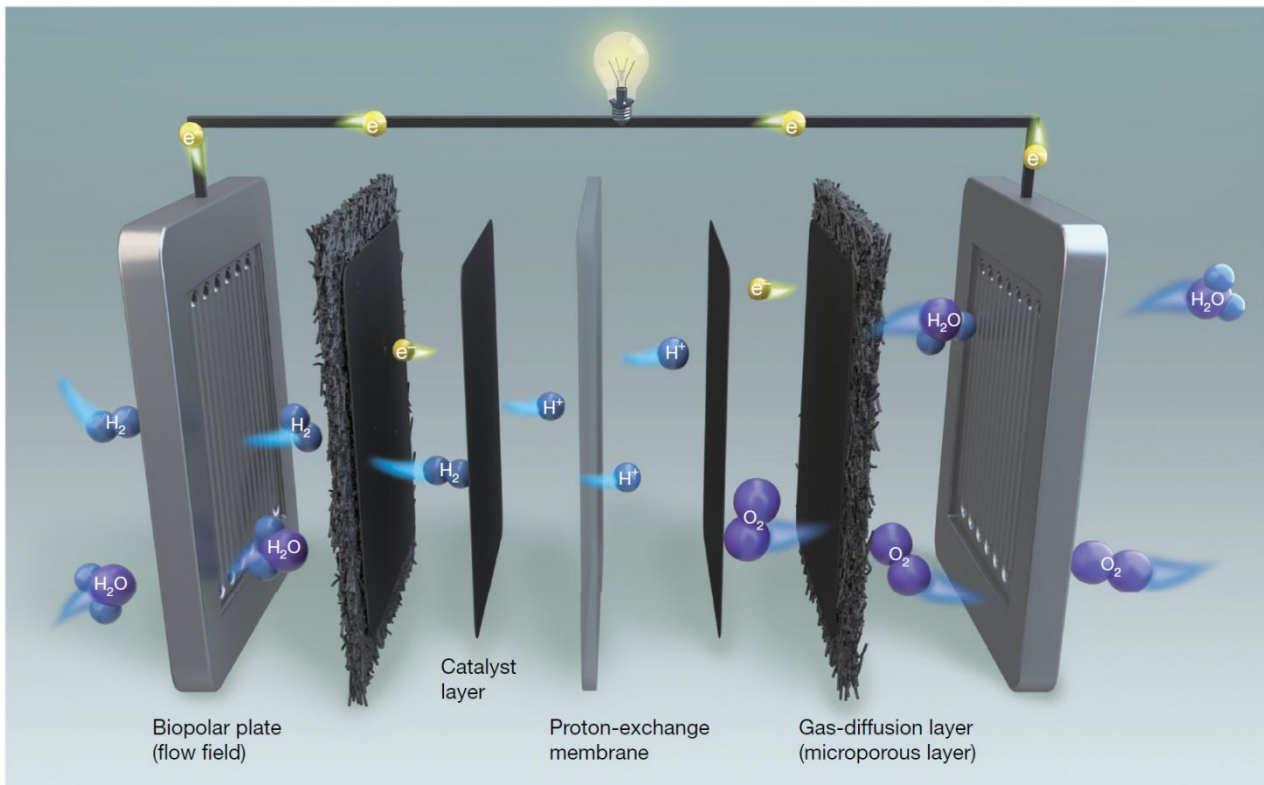


Figure 2. Membrane electrode assembly

3.1.2. Catalyst Technology

Catalysts are everywhere in the electrochemical reactions inside FCEVs. As a substance that catalyzes the reaction process, platinum-based materials are commonly used, but platinum resources are scarce and expensive. Therefore, it is necessary to consider the study of low-platinum catalysts and non-platinum catalysts. Low-platinum catalysts are mainly alloyed or designed with nanostructures to improve the catalytic rate and stability, whereas non-platinum catalysts can be developed to use metallic materials such as iron, palladium, and cobalt to further save costs.

3.1.3. Bipolar Plate Technology

Bipolar plates have the role of separating fuel and oxidizer, collecting current and dissipating heat in fuel cells. The ideal bipolar plate material should have good electrical conductivity, thermal conductivity, corrosion resistance and mechanical strength. Because the power of fuel cell stacks is usually very high, metal bipolar plates are commonly used. Metal bipolar plates have advantages in terms of volume and performance, but the difficulties of their surface treatment technology still need to be solved.

3.1.4. Fuel Cell Reactor Technology

The core of fuel cell is fuel cell stack. Fuel cell stack is composed of several single cells in series, in order to improve the overall performance, the homogeneity of the stack is one of the most important factors, the development of the stack needs to take into account the overall operational requirements and the performance of the main material, to improve the efficiency and power of the reaction process, and to ensure the stability of the operation.

3.2. Drive Motor Technology

The drive motor must be indispensable in the drive of FCEV, how to reduce the size of the drive motor, improve the power and speed of the drive motor has become a hot topic in the current research of related technologies. Drive motors are commonly divided into permanent magnet synchronous

motors and induction motors, of which permanent magnet synchronous motors are characterized by smaller size, powerful power and high conversion efficiency, which have better research value and application prospect compared with other drive motors. In order to select and develop the drive motor, the performance of the drive motor in terms of torque, speed and load characteristics should be better matched, with the purpose of smoothly and efficiently controlling the torque of the motor, so as to achieve better starting, stopping and lifting speeds of the FCEV. Ensure that the conversion power and constant speed efficiency are at a high level, increase the power density, and reduce the size and mass of the drive motor to improve the energy recovery rate during braking. Finally, it is necessary to have environmental universality to ensure the stability and efficiency of the drive motor no matter how to face the working environment. Figure3 shows a permanent magnet brushless motor.

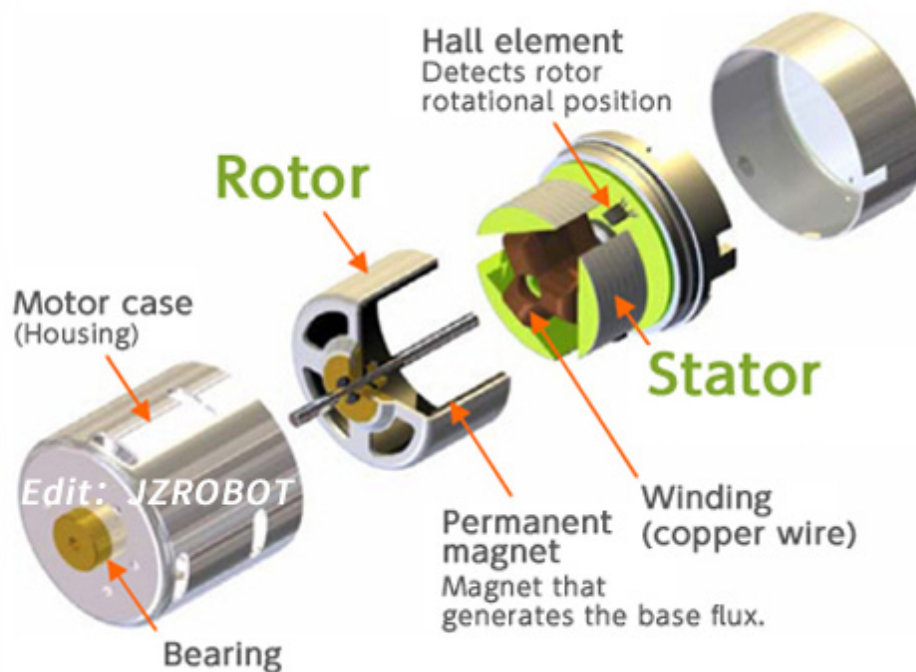


Figure 3. Permanent magnet synchronous motor

3.3. Auxiliary Energy Storage Technologies

Auxiliary storage technologies are closely related to the performance and energy control of FCEVs, therefore, a deeper study of high-performance auxiliary storage technologies can significantly improve the operating attributes and economic value of FCEVs. Auxiliary storage technologies mainly contain batteries, supercapacitors and flywheel batteries. [6]Storage batteries have obvious advantages in enhancing power generation and increasing energy density, supercapacitors are responsible for short-term increase in current charging and discharging and ultra-long range to extend the life of the vehicle, and flywheel batteries are characterized by high energy density, small size and thin and light weight. All three of these technologies are widely used in FCEVs, and now a new track is opening up that combines both of these technologies in order to incorporate their respective strengths.

3.4. Electronic Control Technology

Electronic control technology is also critical in the active technology of FCEVs, which contain a variety of electronic operating systems. Research shows that low voltage power supply can not

provide all kinds of electrical system help for FCEV, using higher voltage power supply can improve the device structure of FCEV. Fuel cell has the characteristics of higher output current and lower output voltage as the temperature rises, so it is difficult for most of the electrical parts to adapt to its current and voltage characteristics, so it is necessary to use DC/AC inverter and DC/DC converter, which can make the stability of the voltage guaranteed, so as to better enhance the power of the fuel cell.

3.5. Hydrogen Supply Technology

Hydrogen supply technology is also an integral part of FCEV technology, including hydrogen storage, transportation and refueling. Hydrogen storage requires a fairly low-temperature environment, and high-pressure hydrogen tanks and hydrogen liquefaction technologies are commonly used today, but these methods present safety hazards as well as costly facilities. Therefore, the development of safe and efficient hydrogen supply technologies (e.g., increased volumetric and mass hydrogen storage densities) will contribute to improved FCEV structures and significant cost savings.

4. DEVELOPMENT OF FUEL CELL ELECTRIC VEHICLES

Traditional fuel vehicles have high demand for oil and cost problems, while the emission pollution of fuel vehicles will also affect the ecological environment and sustainable development, so the non-polluting and energy-saving FCEV has a good development prospect, and many countries around the world have increased their research efforts on FCEV technology.

4.1. Development of Fuel Cell Electric Vehicles in Some Developed Countries

Currently, the global development of FCEV technology is led by Japan and the United States. The Japanese government has formulated a detailed hydrogen energy strategy and plans to realize a hydrogen energy society by 2050, and Toyota Motor Corporation owns a large number of patents in fuel cell technology and has launched commercialized models. The U.S., as one of the major regions for FCEV R&D and demonstration, has made significant progress in FCEV technology with policy and financial support from the U.S. Department of Energy, Department of Transportation, and EPA. GM, Ford, Toyota, Daimler Benz, Nissan, Hyundai and other vehicle companies have participated in FCEV technology demonstration runs in California. In addition, in order to carry out a wide range of vehicle development and demonstration work, the United States in 2006 specifically launched a national public FCEV program. 2011, the United States of America's public FCEV service life of the longest more than 11,000 hours, is expected by the end of 2016, the service life of the public FCEV will reach 20,000 to 30,000 hours.

4.2. Development of Fuel Cell Electric Vehicles in China

China is also actively laying out its hydrogen energy industry, formulating relevant plans and policies, and promoting the R&D and demonstration application of FCEVs. In the field of hydrogen and fuel cell development is also relatively rapid, the government in the "14th Five-Year Plan" clearly support the development of hydrogen industry, many places have launched hydrogen demonstration projects. With technological progress and industrial chain improvement, FCEV market share is expected to gradually increase and become an important part of new energy vehicles in the future. [7] Domestic automakers such as SAIC are also actively developing fuel cell vehicles, striving to achieve technological breakthroughs and commercial applications. Figure4 shows SAIC's FCEV.



Figure 4. SAIC's FCEV

5. CONCLUSION

Fuel cell electric vehicles (FCEVs), as an efficient and clean means of transportation, have great development potential and market prospects. Although it is still facing the problems of high cost, complex facilities and technical difficulties, with the continuous progress of research and the improvement of industrial chain, FCEV will play an increasingly important role in the global automobile industry, and it has a significant strategic value for the protection of ecological environment and the sustainable development of human society.

Nowadays, some countries in the world are becoming more and more mature in FCEV technology research, although China has made significant breakthroughs in the relevant fields, but compared with the degree of research in these countries is still far away, and will face more opportunities and challenges in the future. China's automobile enterprises should respond positively to the government's financial and policy support, improve the research level of FCEV, and accelerate the marketization process of FCEV.

This paper provides an in-depth study of the structure of fuel cell electric vehicles (FCEVs) types, their working principles and core technologies, and shows through relevant information that the complexity of the facilities for producing FCEVs, the high technological needs leading to expensive prices, and the safety, stability and efficiency of hydrogen supply technology need to be improved, so FCEVs still have a long way to go in the process of moving towards marketization.

REFERENCES

- [1] YIN Zhuocheng, WANG He, DUAN Wenyi, et al. Analysis of key technology research status and prospect of hydrogen fuel cell vehicle[J]. *Modern Chemical Industry*,2022,42(10):18-23.
- [2] Zhang Lei. Exploration of key technologies of FCEV[J]. *Electrical Manufacturing*,2014, (06):49-52.
- [3] Jiao JG. FCEV technology in detail (I)[J]. *Automobile Repair and Maintenance*,2016, (10): 97-99.
- [4] Zhang Yu. Working principle and development trend of FCEV[J]. *Automobile Repair and Maintenance*,2024, (01): 47-50.

- [5] YANG Jialuo, SHU Junhao, XU Xin, et al. A review of life cycle analysis of fuel cell vehicles[J]. Journal of Xihua University (Natural Science Edition),2022,41(6):105-112.
- [6] Chen Xingkai. FCEV technology characteristics and key technologies[J]. Agricultural Machinery Use and Maintenance,2023, (09):58-60.
- [7] Liang Hui ren. Current status and trend of battery technology development for electric vehicles[J]. Automotive Testing Report, 2023, (23): 149-151.
- [8] Yu Yuyuan, He Yaohua. FCEV Technology[J]. Automotive Engineer,2009, (05):47-49.