2025 International Conference on Advanced Mechatronics and Intelligent Energy Systems

The Current Situation and Prospects of Hydrogen Fuel Cell Development

AIPCP25-CF-AMIES2025-00002 | Article

The Current Situation and Prospects of Hydrogen Fuel Cell Development

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Abstract. Hydrogen fuel is one of the most promising energy sources in the 21st century. It has the characteristics of being clean and high-energy. Therefore, it is widely applied. Under the current national circumstances, It has made considerable progress. hydrogen fuel cell, Chemical energy is converted into electrical energy through Redox reactions， realizing energy conversion, making full use of clean energy, hydrogen energy. This article aims to provide a detailed account from three aspects: the working principle of batteries, their components, and the current research status in various countries. Finally, the current development status of batteries in the country is prospected. It is hoped that country can overcome technological bottlenecks. Through continuous technological innovation and policy guidance, hydrogen energy will become a major utilized energy source, and, become an important component of the future energy system. the application directions of hydrogen fuel cells will be expanded, and country's goals will be continuously achieved. Thus, take steps that are uniquely characteristic of China. Enhance the country's scientific and technological level and international competitiveness, realize the sustainable development of the country.

INTRODUCTION

Energy is closely related to people's lives and involves various aspects of clothing, food, housing and transportation. Energy also controls the economic lifeline of a country. Traditional energy sources, such as oil, coal and natural gas, are non-renewable, All of them are confronted with the problem of depletion. They all take thousands of years or even hundreds of millions of years to form, It is impossible to be used by us continuously. Meanwhile, during the process of combustion, they will produce a large amount of toxic gases and substances such as carbon dioxide, However, the release of carbon dioxide will cause the greenhouse effect, the sea level to keep rising, and potential dangers threaten people's lives. In response to this situation, China has put forward the "14th Five-Year Plan" and is committed to achieving "carbon peak" by 2030 and "carbon neutrality" by 2035, against the backdrop of rising environmental awareness and increasing demand for clean energy. Renewable energy should be made vigorous use of , and hydrogen energy stands out with its advantages such as being clean and environmentally friendly, and having diverse production methods [1]. Therefore, fuel cells need to be utilized as the energy conversion devices in the hydrogen economy. In theory, fuel cells can convert chemical energy into electrical energy at a 100% efficiency [2]. Although the current actual efficiency of fuel cells is approximately 60% to 70%, the efficiency of ordinary internal combustion engines is only 20% to 35% [3]. It can be seen from this that hydrogen fuel cells also have an important position and play a significant role. China, the European Union, Japan, South Korea and other countries are all vigorously researching and developing hydrogen fuel cells. However, the market is monopolized by a few manufacturers in the United States and Japan [4]. This article will discuss hydrogen fuel cells from several aspects, including their principle, components, existing problems, research conducted by various countries, applications, and prospects for the future.

COMPONENTS AND DISADVANTAGES OF HYDROGEN FUEL CELLS

Depending on the different electrolytes, Hydrogen fuel cells are classified into four types: proton exchange

membrane fuel cells, solid oxide fuel cells, alkaline fuel cells, and phosphoric acid fuel cells. The working principle of a hydrogen fuel cell shown in Figure 1 is that hydrogen is continuously input from the anode. Under the action of the anode catalyst, hydrogen molecules undergo an oxidation reaction and are dissociated into hydrogen ions and electrons, Hydrogen ions pass through the electrolyte layer of the fuel cell and move towards the cathode. Electrons are blocked by the electrolyte and form a current in the external circuit, Oxygen-containing air is continuously fed into the cathode, where it undergoes an electrochemical reaction with hydrogen ions and electrons to produce water as the sole product, while releasing heat. It has achieved energy conversion, transforming chemical energy into electrical energy. As long as hydrogen and oxygen are continuously supplied to the hydrogen fuel cell, it can keep running and constantly carry out energy conversion, thus winning the favor of many enterprises. Thus achieving the conversion. A hydrogen fuel cell consists of two parts: the stack and the auxiliary system. The stack is composed of a proton exchange membrane, a catalyst, a gas diffusion layer and bipolar plates.

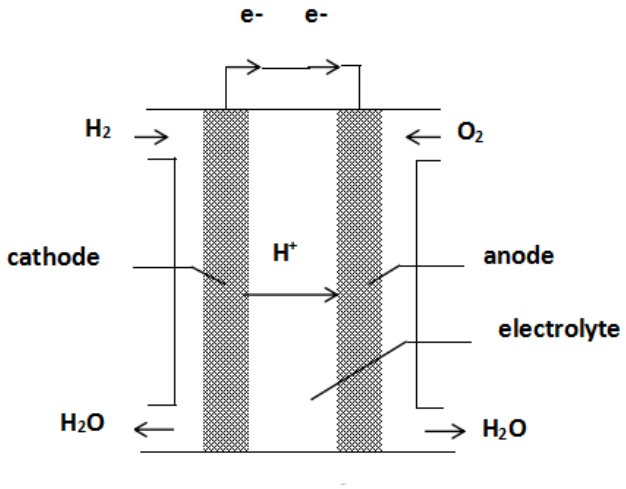

FIGURE1. Proton Exchange Membrane (picture credit:Original)

Proton exchange membrane is a kind of polymer electrolyte membrane and an important component of hydrogen fuel cells, It is a key component for converting chemical energy into electrical energy. It isolates the things produced by the two poles of yin and yang to prevent short circuits, and at the same time it conducts protons. It must have the ability to efficiently pass protons, possess strong stability in a chemical environment, and also have the capacity to prevent the leakage of fuel gas. According to the differences in material composition, proton exchange membranes are classified into perfluorosulfonic acid proton exchange membranes, partially fluorinated proton exchange membranes, and non-fluorinated proton exchange membranes [5]. Proton exchange membranes are usually prepared by melt casting method and solution casting method. The biggest challenge faced by proton exchange membranes is that their performance drops significantly in high-temperature and low-humidity environments [5]. At the same time, it is difficult to achieve a stable state of proton conductivity and stability. To enable proton exchange membranes to play a greater role, it is necessary to find better materials and molecular structures.

Catalyst

Inside a hydrogen fuel cell, redox reactions are constantly taking place. Catalysts can lower the activation energy of the reactions, thereby accelerating the reaction rate. Depending on the materials, catalysts can be classified into platinum catalysts, low-platinum catalysts and non-platinum catalysts, The biggest problem that catalysts encounter during the reaction process is deactivation after poisoning and carbon deposition, Nowadays, Pt/t catalysts have the widest range of applications [1]. Because its surface has a certain amount of activated carbon. At the same time, platinum can effectively adsorb hydrogen and oxygen.it can adsorb a certain amount of carbon deposits, thereby reducing the probability of deactivation. And increase the reaction rate. Another common approach is to use nanostructures to increase the number of active sites, thereby reducing the probability of deactivation. Nowadays,

single-atom catalysts have emerged out of nowhere, pioneering another approach to optimizing the performance of catalysts.

Gas Diffusion Layer

The gas diffusion layer is mostly composed of carbon fibers and is located between the catalyst and the bipolar plate, having a significant impact on the activity of the catalyst. It also plays a significant role in the battery, facilitating gas transmission and ensuring that the gas is evenly diffused over the surface of the catalyst, thereby increasing the contact area and accelerating the reaction rate. Meanwhile, the gas diffusion layer has a good function of electron conduction. The conductivity of the gas diffusion layer will affect the performance of the battery. It will also promptly discharge the generated water to prevent it from hindering the reaction, and it also has functions such as heat conduction.

Bipolar Plate

The traditional flow fields of bipolar plate fuel cells mainly include four configurations: parallel, serpentine, point and interlaced [6]. Among them, the parallel flow field has the poorest performance and is prone to clogging. The bipolar plate separates the anode and cathode plates but connects them at the same time, thus forming a circuit to conduct current，the main functions of bipolar plates are to separate reaction gases, conduct current, support electrodes and discharge water. Bipolar plates possess strong heat conductivity, corrosion resistance and thermal expansion coefficient. According to the material, they can be classified into three major categories: graphite, metal and composite material bipolar plates [7]. Generally speaking, the bipolar plates made of composite materials have the best performance.

Auxiliary System

The auxiliary system is an important part for maintaining the stable operation of fuel cells，It consists of fuel supply, air supply, water and heat management, control, and power output systems, which work in coordination with the stack to enable the operation of the hydrogen fuel cell. In the auxiliary system, the air compressor plays the most crucial role. By increasing pressure, it accelerates the reaction rate. However, the current air compressors are not sensitive enough to detect changes promptly, thus failing to fully utilize the battery's performance. This technical bottleneck requires us to constantly overcome it.

Disadvantages

The multiple components of a hydrogen fuel cell each perform their own duties, making the operation orderly. However, they still work in harmony as a whole to ensure the normal operation of the hydrogen fuel cell. Although hydrogen fuel cells have significant advantages in many aspects and possess energy utilization value, they still have certain drawbacks. (1) There are safety concerns because its main fuel is hydrogen, which is a flammable and explosive gas. Therefore, it is not easy to store and there are always safety hazards. Common methods for hydrogen storage include high-pressure gaseous storage, cryogenic liquid storage, and solid-state storage, but each method has its own drawbacks. If a short circuit occurs inside the battery or the battery's insulating skin is damaged, there is a risk of electric shock and injury if a person touches it. (2) Its cost is too high. Hydrogen is not easy to produce. The commonly used method is electrolyzing water, but this method requires a high cost. The structure of the pool is rather complex and consists of multiple components. For instance, to achieve better performance, the catalyst is typically a Pt/C catalyst, in which the content of Pt is scarce. So the cost is still relatively high. (3) It is also not very stable. As the usage time increases, impurities such as carbon deposits will accumulate on the surface of the catalyst, causing the catalyst to become inactive. At this point, the battery performance will drop sharply. When a battery is in an acidic or alkaline environment, its internal components will gradually corrode, and eventually leakage will occur. Meanwhile, the performance of the battery is also affected by factors such as temperature and pressure. (4) here are many components in hydrogen fuel cells, and each component has its own requirements to achieve maximum efficiency, such as materials. Finding the most suitable materials needs to constantly explore . The technology in the country has not yet reached the level of perfection. There are still some technical bottlenecks that

needs to constantly overcome in order to stand at the forefront of the times.

RESEARCH ON BATTERIES AND THEIR APPLICATIONS IN VARIOUS COUNTRIES

The invention of the battery has a history of over a hundred years. In 1842, William Grove invented the first fuel cell. In 1960, General Electric developed proton exchange membrane fuel cells as the main power source for spacecraft. In 1966, it launched the first fuel cell vehicle. In 1993, Ballard Power Systems developed the first proton exchange membrane bus. In 2001, China included fuel cells in the 863 Program. In 2011, China launched a research and development plan to encourage and guide the development of hydrogen fuel cell technology. In 2020, the world's first liquid hydrogen heavy-duty truck was introduced. The European Union, the United States, Japan, South Korea and China all have high attainments in this aspect and each has its own unique strategy. For instance, the United States focuses on comprehensive layout and diversified applications, Japan implements a technology-leading strategy, and South Korea concentrates on fundamental research and application of fuel cells [8]. After years of research and development, Japan became the first country to master the technology for collecting combustible ice [9]. And Japan has become the most proficient country in the world in the utilization of hydrogen energy. Japan's stationary fuel cells have been applied in commercial and industrial fields [10]. In addition, the number of hydrogen fuel cell buses is also increasing rapidly [11]. Due to Japan's small territory and relatively scarce resources, the emergence of fuel cells has relatively alleviated the problem of resource shortage and accelerated the country's development speed. The European Union, on the other hand, made a significant leap forward by applying batteries in submarines. At present, fuel cells also have relatively wide applications. In the past two years, new energy vehicles have emerged like a meteor. There are Tesla in the United States, NIO, Xiaomi, XPeng and others in China. In addition to automobiles, fuel cells should also be applied in aerospace, electronic products, and household appliances. It is being applied in the fields of transportation, industry, military affairs, etc. Although various countries have conducted certain research on hydrogen fuel cells, However, this technology has not yet reached a mature stage, with problems such as high costs and uncertain safety, so it has not been fully applied in all aspects of life. Keeping making efforts still be needed.

CONCLUSION AND PROSPECT

Under the support of various national strategies, China has increased the utilization of new energy, and hydrogen fuel cells have thus developed and been utilized rapidly. his article mainly elaborates on the working principle, components and research in various countries of hydrogen fuel cells. Hydrogen energy batteries, as an efficient energy conversion technology, have numerous applications in transportation, aerospace, portable power sources and many other fields. They address the potential problems of resource depletion and environmental pollution in the future. At a time when the world is developing new energy sources, China must also keep up with the pace. China should make full use of its vast territory and abundant natural resources such as wind, light and water, fully utilize resources, and constantly adjust the proportion between renewable and non-renewable resources. Realizing the energy transition can not only reduce environmental pollution but also lay a certain foundation for the country's long-term development. Going it alone is not a sustainable solution in the long run. Humbly learning from other countries to improve the own techniques and methods. Strengthen international cooperation and go global. Constantly improve manufacturing technology, constantly innovate and createenhance China's international competitiveness, and achieve autonomy and initiative in manufacturing. Certain policies can also be formulated to provide certain human and material support for the research on hydrogen fuel cells. Meanwhile, expand the market, apply it in all aspects of life, enhance demand, improve infrastructure, making it more convenient and time-saving. With the development of time, hydrogen energy will be utilized to a greater extent and hydrogen fuel cells will play a greater role.

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