Hydrogen Powered Engine and Application

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Abstract. Hydrogen energy, with abundant sources, high energy density, environmentally friendly usage, and zero carbon emissions, is touted as the ideal energy source of the 21st century and has been elevated to a national strategic level by multiple countries. On the one hand, due to the volatility of renewable energy sources such as wind and solar power, it is difficult to directly connect them to the grid for large-scale utilization. The National Development and Reform Commission has explicitly included hydrogen energy in the new energy storage method, which produces hydrogen from renewable energy sources and converts it into terminal energy. This is conducive to promoting the consumption of renewable energy and accelerating the green transformation of the energy structure. On the other hand, China's industrial and transportation sectors are highly dependent on traditional fossil fuels, making decarbonization difficult. Promoting green hydrogen substitution can promote the development of green chemicals and green transportation, and help carbon intensive industries such as industry and transportation achieve carbon neutrality.

Keywords: Hydrogen energy; promoting green hydrogen substitution.

1. Introduction

Nowadays, The United States, Germany, France, Russia, Japan, the United Kingdom, Spain, Portugal and other countries have formulated hydrogen energy development plans and support policies to promote the development of the hydrogen energy industry. On October 5, 2020, McKinsey, in collaboration with major American oil, gas, electricity, automotive, fuel cell, and hydrogen energy companies such as Plug Power, Toyota, Shell, Air Liquide, Microsoft, and SoCa Gas, released a roadmap for the US hydrogen economy. The plan is to establish a competitive hydrogen energy industry with an annual revenue of $750 billion and create 3.5 million jobs by 2050, which can meet 14% of the US energy demand. In July 2020, the European Commission officially released the "Climate Neutral European Hydrogen Strategy", announcing the establishment of the EU Hydrogen Industry Alliance and increasing support for the hydrogen industry. According to the EU's set targets, the proportion of hydrogen energy in the EU's energy structure will reach approximately 13% by 2050. By 2030, the EU will invest an additional 24 to 42 billion euros in the field of electrolytic cells, and by 2050, this investment will reach 180 to 470 billion euros [1]. France, Germany, Russia, Spain, Portugal and other countries have all introduced hydrogen energy investment plans worth billions of euros. In recent years, new energy sources such as wind and solar energy have developed rapidly in China. However, the intermittency of new energy, uneven geographical distribution of resources, and separation of power generation and load centers have limited their large-scale integration into the power grid. The problem of new energy consumption has seriously constrained their development. Using new energy to produce hydrogen can not only solve the problem of "abandoning wind and solar power" in new energy generation, converting electricity into hydrogen energy, but also further reduce the cost of new energy hydrogen production. New energy hydrogen production has the advantages of less geographical environmental constraints, strong scale adaptability, and environmental friendliness, which saves investment and land occupation in the construction of power grids. It can effectively promote the consumption of new energy, expand the utilization of renewable energy, and maximize the use of local superior natural resources. Overall, developing hydrogen energy is a common goal of countries around the world, and it is the truly sustainable energy source. According to the long time period development, its applications mainly focus on the following aspects:

Hydrogen energy can be used in fuel cell vehicles, which generate electricity through the chemical reaction of hydrogen and oxygen to drive an electric motor. Hydrogen fuel cell vehicles have a long range and short hydrogen charging time, making them a powerful supplement to electric vehicles.

Some cities have started deploying hydrogen fuel cell uses and freight vehicles to reduce pollutant emissions in the city. Hydrogen energy can serve as an energy storage medium, converting excess renewable energy sources such as wind and solar energy into hydrogen for storage, and then converting it into electricity when needed. This approach can balance supply and demand fluctuations and enhance the flexibility of the energy system. Hydrogen is an important raw material in industrial processes such as ammonia synthesis and petroleum refining, which can reduce carbon emissions during the process. Hydrogen can be used to replace traditional carbon-based reducing agents and achieve green manufacturing in steel production. Hydrogen energy can be used for power generation in power plants, especially when combined with fuel cell technology, to provide efficient and pollution-free electricity. In some regions, hydrogen energy is used for household heating, hot water, and electricity supply, which are typically combined with solar or other renewable energy systems to achieve higher energy efficiency [2].

2. Hydrogen Power

2.1. Hydrogen supply system

High pressure hydrogen storage tank is used to store hydrogen gas. Storage tanks are typically designed for high pressure (700 bar or 1000 bar) to store hydrogen as efficiently as possible. Hydrogen regulator is used to regulate the high-pressure hydrogen gas in the storage tank to the appropriate pressure and flow required by the fuel cell. And hydrogen filter is used to remove impurities from hydrogen gas to protect the catalyst of fuel cells. Compresses external air to the pressure required by the fuel cell and supplies it to the cathode of the fuel cell. It used to remove dust and pollutants from the air to protect the cathode of fuel cells. Responsible for monitoring and controlling the working status of the fuel cell stack, including current, voltage, temperature, etc. Cooling system generate heat during operation and require a cooling system to maintain a suitable operating temperature. It usually includes a coolant pump and a radiator, powered by fuel cells to drive the wheels of a vehicle. The electric motor can be a DC motor or an AC motor. Power converter converts the direct current output from the fuel cell into the power format required by the electric motor. Power distribution unit distributes electricity to electric motors and other power demand components, such as air conditioning systems and lighting systems.

2.2. Application of Hydrogen Power

2.2.1. Toyota Mirai

The Toyota Mirai is a leading hydrogen fuel cell vehicle designed to promote the development of sustainable transportation. Since its first release in 2014, the Mirai has become a pioneer in the field of hydrogen powered vehicles, representing Toyota's innovation in environmentally friendly car technology. Mirai adopts a hydrogen fuel cell system, which generates electricity through the chemical reaction of hydrogen and oxygen to drive the car, while only emitting water vapor and almost no pollutants. The new generation Mirai has a range of over 400 miles (approximately 644 kilometers), making it highly practical for daily use. The Mirai's refueling time is about 5 minutes, similar to the refueling time of traditional fuel vehicles, improving the user experience? Equipped with Toyota's latest safety technology, such as Toyota Safety Sense, providing multiple active safety functions to ensure driving safety. Mirai's exterior is stylish and streamlined, while the interior emphasizes luxury and comfort, equipped with advanced infotainment systems and high-quality materials. As a hydrogen fuel cell vehicle, the Toyota Mirai not only emits almost no greenhouse gases during vehicle operation, but also promotes the development of hydrogen infrastructure and the

application of renewable energy. Toyota's goal is to help achieve a carbon neutral future by promoting hydrogen technology [3].

The fuel cell stack components include the fuel cell stack, auxiliary components (such as hydrogen circulation pumps), and fuel cell boost converters. Integrating these components can achieve smaller, lighter, and cheaper fuel cell stack components. Toyota's breakthrough in fuel cell technology has led to the launch of a new type of fuel cell that is smaller, lighter, and has stronger performance. The newly stacked volumetric power density is 3.1 kW/L, which is world-class and can be installed under the floor of a sedan.

2.2.2. Hydrogen plane

The future feasibility of hydrogen powered aircraft is a highly anticipated topic, especially in the context of addressing climate change and reducing carbon emissions in the aviation industry. Here are several key points regarding the feasibility of hydrogen powered aircraft. Hydrogen fuel cells have achieved success in ground transportation and have high energy conversion efficiency. It is feasible to apply this technology to the aerospace field, and many companies and research institutions are developing related technologies. Hydrogen needs to be stored in high-pressure or liquid form, which poses challenges to design and safety. However, the development of modern materials and engineering technology has made these storage systems increasingly safe and efficient. The cost of hydrogen production, storage, and transportation remains high. Although renewable hydrogen (hydrogen generated through electrolysis of water) is receiving increasing attention, its large-scale production and infrastructure construction still require investment. The level of acceptance of new technologies by airlines and consumers will affect the economic feasibility of hydrogen powered aircraft. If hydrogen powered aircraft can provide cost and performance comparable to traditional aircraft, the market outlook will be even more optimistic. The main emission of hydrogen powered aircraft is water vapor, which can significantly reduce greenhouse gas emissions compared to traditional aviation fuels. This advantage makes hydrogen powered aircraft competitive in the context of increasingly strict environmental regulations [4].

The production and use of hydrogen require a comprehensive environmental impact assessment, including its impact on water resources and land use, to ensure its true sustainability. Now Hydrogen fueled aircraft require specialized hydrogen refueling infrastructure. The current airports and airlines need to invest in the construction of relevant facilities to support the production and storage of hydrogen. Cooperation and policy support between governments, airlines, and energy companies are crucial for infrastructure development. Hydrogen has a higher energy density than batteries, theoretically allowing for longer range. However, the design of hydrogen powered aircraft needs to ensure competitiveness in terms of range, speed, and payload capacity. Although small prototypes have been successfully tested, the development of large-scale commercial hydrogen powered aircraft still requires time. Governments and enterprises around the world are increasing their investment in the research and development of hydrogen powered aircraft, promoting technological progress and application. Some airlines and manufacturers are conducting demonstration flights to verify the feasibility of hydrogen powered aircraft and pave the way for future commercialization.

Boeing successfully flew a small aircraft powered by hydrogen fuel cells on April 3, 2008. Boeing claims that this is the first time in the history of world aviation, indicating that the aviation industry will be more environmentally friendly in the future. But Boeing acknowledges that this technology is unlikely to provide primary power for large passenger aircraft [5]. Boeing conducted three test flights of hydrogen fuel cell aircraft in Ocania, Spain from February to March 2008, which is of historical significance. Small aircraft use a hybrid of traditional batteries and hydrogen fuel cells for takeoff and climb processes. After climbing to a cruising altitude of 1000 meters, the aircraft cuts off traditional battery power and relies solely on hydrogen fuel cells for power. The plane flew at an altitude of 1000 meters for about 20 minutes at a speed of about 100 kilometers per hour. This technology is of great significance to Boeing and also fills the future of the aviation industry with green hope. The small aircraft is modified from the Austrian "Diamond" and two seaters propeller powered glider, and is equipped with proton exchange membrane fuel cells and lithium-ion batteries

inside. The small aircraft has a wingspan of 16.3 meters, a fuselage length of 6.5 meters, weighs approximately 800 kilograms, and can accommodate two people. During the test flight, there was only one pilot on board. In the cabin, traditional batteries are placed in the only passenger seat, and there is an oxygen tank behind the pilot that resembles that used by divers. Boeing said that the aircraft can fly continuously for up to 45 minutes without producing any noise. Hydrogen fuel cells generate electricity through the process of converting hydrogen into water, without producing greenhouse gases. Besides heat, water vapor is the only byproduct generated by hydrogen cells.

Boeing's hydrogen fuel cell aircraft has brought technological breakthroughs, but the "Boeing (Europe) Research and Technology" department states that hydrogen fuel cells can provide flight power for small aircraft, but are unlikely to provide primary power for large passenger planes. This technology may provide auxiliary power for large aircraft, but it requires technological breakthroughs.

In the context of rising fuel prices, environmental pollution, and global warming, the demand for cleaner, safer, and more efficient modes of transportation is rapidly increasing. Boeing's hydrogen fuel cell aircraft has brought technological breakthroughs, but according to Escatti, head of research and technology at Boeing Europe, hydrogen fuel cells can provide flight power for small aircraft, but are unlikely to provide primary power for large passenger planes. Boeing's engineer in charge of test flights, Neves Lapenna, said that this technology may provide auxiliary power for large aircraft, but this requires a technological breakthrough. Boeing said it will continue to develop the potential of hydrogen fuel cells to improve the environment. The International Energy Agency states that promoting the use of hydrogen and hydrogen fuel cells can reduce the consumption of three types of energy that can produce greenhouse gases: oil, natural gas, and coal [5].

3. Summary

As the real non-polluted petrol, the development of hydrogen powered engine become more essential. Major developed countries attach great importance to the development of hydrogen energy from the perspectives of resources and environmental protection. Currently, hydrogen energy and fuel cells have been commercialized in some specialized fields.

In 2017, the installed capacity of fuel cells worldwide reached 670 megawatts, with a mobile installed capacity of 455.7 megawatts and a fixed installed capacity of 213.5 megawatts. As of December 2017, the cumulative sales of fuel cell passenger vehicles worldwide have approached 6000 units. The Toyota Mirai sold a total of 5300 vehicles, including 2900 in the United States, 2100 in Japan, and 200 in Europe, accounting for over 90% of the world's total sales of fuel cell passenger vehicles. As of the end of 2017, there were a total of 328 hydrogen refueling stations worldwide, with 139 already in operation in Europe, 118 in Asia, and 68 in North America.

The research and commercialization of hydrogen fuel cells and hydrogen fuel cell vehicles are rapidly developing in Japan, the United States, and Europe, with continuous technological innovation in stages such as hydrogen production.

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