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Research on the development status and countermeasures of hydrogen fuel cell vehicle industry in China

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Abstract: Hydrogen fuel cell vehicle is an important direction of global automotive power transformation and upgrading. It has advantages such as good environmental performance, high conversion efficiency, short filling time and long driving distance. It is one of the important directions for the sustainable development of the future automobile industry, but also an important part of the construction of low-carbon transportation system, and a key field of hydrogen energy utilization.

Keywords: Hydrogen fuel cell vehicle; Reactor; Power battery; Drive motor; Pilot operation.

1. Development history of fuel cell vehicles

1.1. Development history of foreign hydrogen fuel cell vehicles

Foreign hydrogen fuel cell vehicles are mainly used in the field of passenger vehicles. As early as 1966, human beings started to explore the field of hydrogen energy powered vehicles. The hydrogen fuel cell vehicle developed by General Motors for the "moon shot" has shown good performance in durability and coping with extreme climate. In the 1990s, Japan and South Korea took the lead in the research and development of hydrogen fuel vehicles. Honda, Toyota and Hyundai Motor entered the research and development of hydrogen fuel vehicles successively. Since 2013, Japanese and Korean companies have released their research and development results successively. A number of fuel cell vehicles, including Hyundai Tucson FCEV, Toyota Mirai, and Honda Clarify, have successfully penetrated the European and American automobile markets and embarked on the industrialization process. With the excellent performance of the above models and the ability of new concepts, it has set off a "hydrogen energy fever" in the United States, Canada, Japan and some European countries, and pioneered the demonstration application of hydrogen energy vehicles in the field of passenger vehicles. At the same time, hydrogen fuel cells have been commercialized in special vehicles such as city buses and forklifts. However, from the perspective of market size, foreign hydrogen fuel cell vehicles are mainly used in the field of passenger vehicles.

1.2. Development history of hydrogen fuel cell vehicles in China

China's hydrogen fuel cell demonstration applications mainly focus on commercial vehicles. As early as in the "Tenth Five-Year Plan" period, the state established the technology R&D layout of HEV, BEV and FCVS as "three vertical" and battery, motor and electric control as "three horizontal" in the "863 Plan Major Projects for Electric Vehicles". Since 2001, China has officially started the research and development of fuel cell vehicles, and then gradually incorporated hydrogen fuel cell and technology into a series of top-level design documents such as the "Energy Saving and New Energy Vehicle Development Plan (2021-2020)" and the "13th Five-Year Plan" National Science and Technology Innovation Plan. The development of hydrogen fuel cell technology continues to accelerate. Demonstration applications of hydrogen fuel vehicles have also begun. During the 2008 Beijing Olympic Games, three hydrogen fuel cell buses jointly developed by Beiqi Foton and Tsinghua University successfully completed the service vehicle task and one-year demonstration operation. The 20 fuel cell cars jointly produced by Shanghai Fuel Cell Vehicle Power System Co., Ltd. and Shanghai Volkswagen also undertook the official car reception tasks of the Ministry of Science and Technology, the Organizing Committee of the Olympic Games and the Beijing Transportation Bureau during the Olympic Games. During the 2010 Shanghai World Expo, Shanghai was the first city in China to develop and apply hydrogen fuel cell vehicles. 100 hydrogen fuel cell sightseeing vehicles and 4 hydrogen fuel cell buses were put into use. Since then, China's hydrogen fuel cell vehicle development has entered the market demonstration application stage on the eve of industrialization. Different from foreign countries, the demonstration application of hydrogen fuel cells in China is mainly concentrated in the field of commercial vehicles, while the field of passenger vehicles is still in the "blue ocean" state.

2. Environmental analysis of hydrogen fuel cell vehicle industry development in China

2.1. Policy environment

2.1.1. The State encourages the development of hydrogen fuel cell automobile industry with clear macro guidance

In recent years, the CPC Central Committee and The State Council have attached great importance to the development of the fuel automobile industry and introduced a "package" of supporting policies, which has initially formed an industrial policy system covering macro-synthesis, industry management, fiscal and tax incentives, scientific and

technological innovation, etc. In 2019, hydrogen energy development was included in the Government Work Report for the first time, and it was clearly stated to "promote the construction of energy filling infrastructure such as charging and hydrogenation stations". In March 2019, the Ministry of Finance and other four ministries jointly issued the Notice on Further Improving the Fiscal Subsidy Policy for the promotion and application of new energy Vehicles, pointing out that local governments should improve their policies and no longer provide subsidies for the purchase of new energy vehicles (except new energy buses and fuel cell vehicles) after the transition period. To support the charging (hydrogenation) infrastructure "short board" construction and supporting operation services. In 2020, the Development Plan for New Energy Vehicles (2021-2035) issued by The State Council and the Technology Roadmap for Energy Saving and New Energy Vehicles (Version 2.0) issued by the China Society of Automotive Engineering made clear plans for the domestic hydrogen fuel supply system and the commercial development path of fuel cell vehicles. Two documents were issued to inject a boost and target guidance for the development of China's hydrogen power industry. In 2021, the development of hydrogen fuel cell vehicles appeared for the first time in the "Five-Year Plan". It is proposed that the incubation and acceleration plan of hydrogen energy industry will be implemented in the future to plan a batch of hydrogen energy industries, among which fuel cell vehicles have broad prospects as the largest application scenario of hydrogen energy. In March 2022, the National Development and Reform Commission and the National Energy Administration issued the Medium and Long-Term Plan for the Development of Hydrogen Energy Industry (2021-2035), which considers fuel cell vehicles as an important application of hydrogen energy, vigorously develops the fuel cell vehicle industry, focuses on promoting medium and heavy vehicles, and gradually establishes the complementary development mode of fuel cell vehicles and lithium-battery pure electric vehicles. It can be seen that the national development of hydrogen fuel cell vehicle macro guidance has been clear, and fuel cell vehicle will become one of the future new energy vehicle development direction.

2.1.2. The State supports qualified and motivated regions and enterprises to take the lead in the commercial demonstration application of hydrogen fuel cell vehicles

Since 2009, the government has introduced incentive policies to support hydrogen fuel cell vehicles, but the policies mainly focus on the consumption and purchase end, which is equivalent to disguised subsidies to the production enterprises. In 2020, the Ministry of Industry and Information Technology made it clear that in order to promote the construction of a complete industrial chain of fuel cell vehicles and form an industrial development pattern with reasonable distribution, different priorities and coordinated promotion, and the future national policy support should be transferred to the middle and upstream of the industrial chain, and encouraged regions and enterprises with conditions and enthusiasm to take the lead in commercial demonstration application. Based on the above principles, in September 2020, five ministries, including the Ministry of Finance and the Ministry of Industry and Information Technology, jointly issued the Notice on the Demonstration Application of Fuel cell Vehicles, organized nationwide collection of hydrogen fuel cell vehicle demonstration city clusters, and adjusted the central government's financial support for hydrogen fuel cell vehicles from purchase subsidies to support the demonstration application of fuel cell vehicles in city clusters. Up to now, the state has approved five fuel cell vehicle demonstration application clusters led by Daxing District of Beijing, Shanghai, Foshan City of Guangdong Province, Zhengzhou City of Henan Province and Zhangjiakou City of Hebei Province, forming a "3+2" demonstration pattern. During the four-year demonstration period, each city cluster will receive up to 1.7 billion yuan (An additional 170 million yuan will be awarded for overachievement) from the central government.

Policy support will gradually shift from the application level to the core technology

Before the "14th Five-Year Plan" development period, there was a significant difference in the focus of foreign and domestic policy support. Different from foreign policies that focus on both technology and application, in the early stage of the development of China's fuel cell industry, policies tend to be at the application level, mainly to mobilize the enthusiasm of enterprises at the node of the industrial chain and improve the market cognition ability. However, there is still a big gap between China and Japan, the United States, South Korea, the European Union and other major countries and regions in terms of basic technology support. After entering the "14th Five-Year Plan" development period, under the overall development background of building a "double cycle" at home and abroad, China's policy orientation in the development of hydrogen fuel cell vehicles has also changed. The state will focus on supporting breakthroughs in key core technologies, and build an independent, controllable, safe and efficient hydrogen fuel cell vehicle industry chain and supply chain. In the future, the central government will increase support for R&D and innovation, and give key rewards to the industrialized application of key components with independent intellectual property rights.

2.1.3. Local governments have introduced industrial support policies, but the policy system needs to be detailed

Driven by national top-level design, local governments are developing the hydrogen fuel cell vehicle industry. On the one hand, local governments are there to practice the concept of green development. On the other hand, it aims to attract enterprises related to the hydrogen energy industry chain to settle down in the city, promote the adjustment of local industrial structure, and gradually start commercial application. Up to now, there are more than 10 plans for the hydrogen energy industry at the provincial and municipal level, and more than 30 special plans for hydrogen energy at the prefecture-level and district-level. Many provinces and cities, including Guangdong, Jiangsu, Shandong, Anhui, Sichuan, Zhejiang, Shanghai, Fujian, Hebei and Beijing, have introduced corresponding policies to promote subsidies. Local governments have set up hydrogenation station construction goals, and put forward development goals and action plans from industrial output value, hydrogen fuel cell vehicle promotion, stationary power generation application, enterprise cultivation and other aspects, and supporting measures of different degrees such as vehicle purchase subsidies, gas subsidies, hydrogenation station construction subsidies. However, it is worth noting that the current support policies are mainly subsidies, and there is little mention of non-fiscal and tax policies such as creating diversified application scenarios for hydrogen fuel cell vehicles.

Moreover, the policies and measures proposed by most regions are too "idealistic" and lack details of implementation.

2.2. Market environment

2.2.1. The hydrogen fuel cell vehicle industry is speeding up its demonstration phase

Driven by the development of the "New Four Modernizations" of automobiles, the global consensus on the development of hydrogen energy industry has been formed. By the end of 2021, nearly 50,000 hydrogen fuel cell vehicles have been promoted worldwide, and 659 hydrogen refueling stations have been built. China is the largest consumer market for new energy vehicles and a country producing hydrogen. By the end of June 2022, the total number of fuel cell vehicles used and promoted had exceeded 10,000, and 270 hydrogen refueling stations had been built in total, gradually forming network coverage. Foreign hydrogen fuel cell vehicles took the lead in the demonstration operation in the field of passenger vehicles, and gradually spread to the field of commercial vehicles such as public transport and fuel cell forklift trucks. For example, Toyota's Mirai, Honda's Clarity and Hyundai's NEXO are all models of hydrogen fuel cell passenger vehicles. Different from foreign countries, China has started early demonstration of hydrogen fuel cell vehicles mainly in the field of commercial vehicles. Hydrogen fuel cell buses were put into mass production during the Beijing Olympic Games and Shanghai World Expo. However, in the field of passenger vehicles, there is no autonomous FCVS that have been mass-produced. However, at present, SAIC Motor, Great Wall, Haima and other independent brand enterprises have begun to carry out the research and development layout of hydrogen fuel cell passenger vehicles. It is expected that around 2025, China's hydrogen fuel cell passenger vehicles will usher in a scale explosion, becoming the "singularity" of fuel cell "both passenger and commercial development".

2.2.2. Large-scale application of hydrogen fuel cell vehicles is coming soon

With the gradual maturity of China's fuel cell commercial vehicle market and the realization of mass production of autonomous passenger vehicles, it is expected to achieve large-scale application in the next 5 to 10 years, and will effectively drive the construction of an independent and complete industrial chain and supply chain system. According to "Energy Saving and New energy Vehicle Technology Roadmap 2.0", it is predicted that the capacity of fuel cell system will exceed 10,000 sets per enterprise in 2025 and 100,000 sets per enterprise in 2035. By 2035, the number of fuel cell vehicles in China is expected to exceed 1 million. At the same time, with the emergence of scale effect and breakthroughs in key technologies, the production cost of fuel cell vehicles will decrease significantly. It is estimated that by 2025, the production cost of passenger vehicles will not exceed 300,000 yuan, and the production cost of commercial vehicles will not exceed 1 million yuan. By around 2040, the life-cycle cost of a fuel-cell vehicle will be equal to that of an all-electric model with the same range.

2.3. Technical environment

2.3.1. Most performance indexes of China's FCV commercial vehicles are equivalent to those of foreign countries, and hydrogen consumption index and vehicle cost have certain advantages

As the market gradually matures, fuel cell vehicle production and sales will be significantly increased. With the support of major national projects, China has made certain progress in fuel cell vehicle technology. It has preliminarily mastered core technologies such as fuel cell reactor and key materials, power system and core components, vehicle integration and hydrogen energy infrastructure, and basically established a fuel cell vehicle power system technology platform with independent intellectual property rights. It has also initially formed a supporting research and development system of fuel cell system, power battery, DC/DC converter, drive motor, hydrogen storage system and other key components, and has the production capacity of thousands of fuel cell vehicles and their power systems.

2.3.2. In terms of hydrogen production technology, China has a variety of hydrogen sources, and the development of green hydrogen production technology has become an inevitable trend

China is rich in hydrogen sources, and different hydrogen production methods lead to significant differences in carbon emissions and hydrogen cost. At present, China's hydrogen production methods mainly include purification of industrial by-product hydrogen, hydrogen production from fossil energy and hydrogen production from electrolytic water. Among them, industrial by-product hydrogen belongs to "gray hydrogen", and hydrogen production from fossil energy belongs to "blue hydrogen". Both of them will produce a large amount of carbon dioxide in the process of hydrogen production, and the purity of directly obtained hydrogen is relatively low, so it will be costly to purify it to the purity of vehicle hydrogen. Hydrogen produced by electrolytic water production belongs to "green hydrogen", which has relatively high purity and is easy to combine with renewable energy. It is considered to be the most potential green hydrogen energy supply source in the future. However, electrolytic water process will consume a lot of power resources, and the cost is higher than the previous two methods, so it does not have the conditions for large-scale production in the short term. At present, industrial by-product hydrogen is regarded as the priority hydrogen source supplier in the initial stage of commercialization of hydrogen energy industry, which is widely used in the demonstration application stage of fuel cell vehicles. In addition, China is currently actively exploring new hydrogen production technologies, such as biomass hydrogen production, photochemical hydrogen production, thermal hydrogen production and other cutting-edge technologies.

2.3.3. In terms of hydrogen storage and transportation technology, high pressure gas storage and transportation, low temperature liquid storage and transportation is an important development trend in the future

Hydrogen is the lightest of all elements. Hydrogen is gaseous at room temperature and pressure, and its density is only 0.0899kg/m3, which is one thousandth of water. Therefore, its high-density storage and transportation has been a worldwide problem. Hydrogen energy storage in China mainly includes high-pressure gaseous hydrogen storage, low-temperature liquid hydrogen storage and organic liquid hydrogen storage. Hydrogen transportation can be divided into gaseous, liquid and solid transportation. High pressure gaseous hydrogen storage is the most commonly used and mature hydrogen storage technology at present. Its storage method is to compress hydrogen into a high-pressure resistant vessel at high pressure. It has the advantages of simple structure, low energy consumption for compressed

hydrogen preparation, fast filling and discharge speed, but this method has small volume specific capacity and poor safety performance. Low temperature liquid hydrogen storage has advantages of high purity and high density, which is an important direction for the development of hydrogen storage and transportation technology in the future. However, this method has high requirements for storage, frost resistance, pressure resistance and strict insulation, and is expensive. At present, China is not open enough to this technology, and it is only used in aerospace and aviation fields that do not care much about cost and rapidly consume hydrogen in a short time.

2.3.4. In terms of hydrogenation station technology, China is still dominated by external hydrogen mode

At present, hydrogenation station technology comes from natural gas filling station. There are two main ways: in-station hydrogenation station technology and external hydrogenation station technology. The technology of in-station hydrogen production and hydrogenation station comes from the principle of natural gas pipe network standard filling station or photovoltaic panel electrolytic water hydrogen production, that is, there is hydrogen production equipment in the hydrogenation station to produce hydrogen. External hydrogen supply and hydrogenation station technology comes from the principle of natural gas mother station and sub-station, that is, the hydrogen is produced from the external factory (the mother station provides the hydrogen source), and is pressurized twice by the hydrogenation station (sub-station) to complete external hydrogenation. Hydrogenation stations that use in-station hydrogen production have high construction cost and difficult approval. Currently, hydrogenation stations in Europe and the United States mainly use this technical route to produce hydrogen through in-station electrolytic water. There is no economic advantage for hydrogen production in domestic stations. At present, almost all existing hydrogenation stations adopt external hydrogen supply technology.

2.4. Competitive environment

2.4.1. Local governments have accelerated the layout of the hydrogen vehicle industry, forming seven development clusters

In recent years, the strategy of developing new energy vehicles has formed a global consensus. As an important branch of the development of new energy vehicles, hydrogen fuel cell vehicles have aroused a large amount of capital enthusiasm, and the layout of hydrogen fuel vehicle industry has entered an era of acceleration. Under the catalytic drive of national and local policies, China has formed seven industrial clusters: East China, North China, South China, Central China, Northeast China, Northwest China and Southwest China, each of which has its own competitive advantages. In addition, China has started the early demonstration application and commercialization exploration of hydrogen fuel cell vehicles, and actively carried out the construction of hydrogenation station infrastructure.

2.4.2. Self-owned brands shall formulate FCEV passenger car development plans to seize the blue ocean passenger car market

Based on the global, for "passenger cars adopt pure electric technology, commercial vehicles adopt hydrogen energy technology" seems to have become a compromise consensus, forming a state of no violation. However, from the perspective of market, fuel cell vehicle ownership in foreign countries is still dominated by passenger vehicles, while the demonstration application of hydrogen fuel cell in China is mostly concentrated in the field of commercial vehicles (buses, buses, sightseeing vehicles, etc.). The self-owned brand FCEV passenger vehicle has not achieved mass production, and the fuel cell passenger car segment is still in the state of "blue ocean". But at present, the domestic "Lithium batteries for passenger cars and hydrogen batteries for commercial vehicles" is only the national industrial balance strategy at the present stage. The domestic mainstream independent brands have never given up the research and development and layout of fuel cell passenger vehicles. When the market, technology, infrastructure development is ready, there will present a centralized "outbreak" situation. In 2020, MAXUS, Great Wall, Guangzhou Automobile, Changan and other independent enterprises have released a number of FCEV passenger cars, and included in the national Ministry of Industry and Information Technology recommended directory. In 2021, Dongfeng successfully developed the first domestic full-power fuel cell passenger vehicle -- "Dongfeng Qingzhou H·e". On April 21, 2022, Changan Automobile released the C385 hydrogen fuel cell sedan; and In July, FAW announced the completion of trial production of the first all-new Hongqi H5 fuel cell passenger car.

3. Suggestions on the development of China's hydrogen fuel cell vehicle industry

3.1. National Level

Strengthen top-level design, and constantly improve the policy system and standard system. Focus on guiding key generic forward-looking technology breakthroughs to solve the bottleneck of the system, storage and transportation links. Continue to promote the high-quality development of hydrogen fuel cell industry demonstration application. To carry out international cooperation and promote domestic demonstration and industrial development.

3.2. Local Level

Take national fiscal and tax policies as the starting point, leading the declaration or join the demonstration city group. Design industrial chain layout and hydrogenation station construction. Encourage existing local enterprises to improve their R&D and innovation capabilities, and give financial incentives to major technological innovations. Promote the development of a sound industrial ecology integrating production, education, research and application.

3.3. Enterprise Level

Grasp the development opportunities of hydrogen fuel cell vehicles, focusing on the hydrogen fuel cell passenger vehicle industry to accelerate the layout and seize the market opportunities. At the same time through technological innovation and policy support to reduce the cost of production.

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