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Current status and prospects of fuel cell vehicle application

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Abstract. With the continuous development and progress of industrial technology, the fossil fuel reserves of the earth are decreasing day by day, and it is more and more difficult to maintain the current energy demand. All sectors of the world are looking for an effective alternative to traditional energy. Hydrogen, known as the clean fuel of the 21st century, has gradually come into people's view because of its high combustion heat value and no pollution of the products after combustion. This paper discusses construction characteristics and working principle of fuel cell vehicles, to prove that the environment problems can be reduced by them. It first introduces the advantages of fuel cells, it produces almost no pollution, thus alleviating the greenhouse effect. It is of the main reasons why FCVs are becoming more and more popular. Secondly, the author also introduces the structure of fuel cell vehicles by comparing their similarities and differences with ordinary cars. The control systems of fuel cell vehicles have also been introduced.

Keywords: Fuel Cell Vehicle, Construction Characteristics, Working Principle, Current Status.

1. The first section in your paper

With the continuous development and progress of industrial technology, the fossil fuel reserves of the earth are decreasing day by day, and it is more and more difficult to maintain the current energy demand. All sectors of the world are looking for an effective alternative to traditional energy. Hydrogen, known as the clean fuel of the 21st century, has gradually come into people's view because of its high combustion heat value and no pollution of the products after combustion. In addition, if hydrogen energy can be applied to industrial development, it will bring huge revolution and advantages to energy [1]. First, because the hydrogen reserves on the earth are very rich, we can obtain the required hydrogen energy by electrolysis of water; The product of the second hydrogen energy is only water, without pollution. It can be seen that hydrogen energy, as a clean energy, its application and promotion will bring great benefits to people. According to investigation and research, the development of hydrogen powered fuel cells in the current form of electric energy is gradually increasing and getting more and more attention [2]. Therefore, the fuel cell vehicle, a vehicle made by combining these two technologies, has become a solution for countries to reduce carbon emissions. A fuel cell vehicle can also be considered an electric vehicle, but you can fill the battery with fuel in five minutes instead of waiting hours for a full charge. This also means that consumers can better transition and adapt to this change from a fuel car to a new energy vehicle. This article will focus on an overview of the technical features of the Fuel Cell Vehicle (FCV) and its future outlook.

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2. Features of FCV

Nowadays, the research on fuel cell vehicles attracts the attention of numbers of scientists. Fuel cells currently have the most potential in transportation applications, but also in energy storage, military applications and other fields. The research and development of hydrogen fuel cell vehicles has been widely carried out and put into the market in Japan, the United States, South Korea and other countries. The ownership of fuel cell vehicles in the United States accounts for 50% of the world, and there are 25,000 fuel cell delivery vehicles alone. Japan's Toyota, Honda and South Korea's Hyundai have launched their own fuel cell vehicles [1].

2.1.Advantage of fuel cell

Why is FCV so popular? The most significant advantage is that it causes little pollution, so it can help reduce greenhouse gas emissions. This can reduce the occurrence of greenhouse gases at the source and reduce the pollution to the environment. In addition, because hydrogen has a large calorific value, its generated energy can also help power generation. In the long run, the automobile industry must take the road of sustainable development. Oil, natural gas, coal and other resources are non renewable and will eventually be exhausted. The emergence of hydrogen energy undoubtedly points out the development path for the future energy development of mankind and helps mankind find new light in energy exploration. Humans will eventually use renewable or alternative energy sources. According to the calculation, 9 tons of water can produce 1 ton of hydrogen (and 8 tons of oxygen). The calorific value of hydrogen combustion is 28900 kcal/kg. In addition, hydrogen and oxygen will produce water when burning, and water can be recycled. Obviously, hydrogen production from water can form an endless positive feedback loop between production and use. Figure 1 shows the appearance of the fuel cell [3].

Figure 1. What fuel cell looks like [3].

2.2.The construction of FCV

Family cars and FCVs share several similarities in that the powertrain, chassis, car electronics, and body are all merged into one unit. The fuel cell system and an electric motor are used in the vehicle's powertrain to propel the vehicle forward. Hydrogen is utilized to generate energy, which is then stored in pressure tanks inside of vehicles. This energy is converted into electricity by the fuel cell stack, with the help of batteries, which powers electric motors. While there are not many differences in practice between fuel cell vehicles and fully electric vehicles, fuel cell vehicles have substantially smaller battery capacities. Because all energy is stored in the battery of pure electric car, the FCV just uses the battery to help stabilize the fuel cell's power output: taking in extra power when demand is low and releasing it when demand is high. In theory, pure electric vehicles are more energy efficient, but the excessive battery weight reduces this advantage, especially for heavy vehicles used for long-distance transportation. Pure electric cars must add more battery capacity for every extra mile driven, adding extra weight to the vehicle. In Tesla's electric heavy truck model, for example, the battery is expected

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to weigh 4.5 tons. Fuel-cell cars don't have that problem, because the hydrogen they carry is far less mass than the battery needed for the same amount of energy. This is because hydrogen has a higher specific energy - about 120MJ/kg, compared with 5MJ/kg for batteries. Other than the powertrain, the vehicle's components are essentially the same. The vehicle chassis includes transmission, steering, braking and running systems. The vehicle electronics system consists of chassis control systems, safety systems and vehicle electronics such as infotainment/communications, advanced driver assistance systems (" ADAS ") and sensors. Finally, the body includes the body, the seats and the interior.

2.3.Electricity used to control the movement of the car

An effective system architecture and control technique are needed to improve fuel cell-based propulsion systems. To get the necessary hydrogen for the fuel cell stack's input, the fuel is treated in a fuel reformer. Typically, oxygen for fuel cells comes from ambient air. Direct current and heat are produced in a fuel cell stack by the reaction of hydrogen and oxygen. The power regulator controls the fuel cell stack's output voltage to provide the inverter's needed voltage. The inverter will convert the direct current (DC) into alternating current with variable voltage and frequency in order to power the motor. Batteries or supercapacitors are usually attached to the fuel cell system to provide supplementary power and start the system. The battery unit and fuel cell stack provide the power needed to drive the system [3]. The power regulator must elevate the voltage of the fuel cell stack to roughly 300V of the battery voltage if the voltage required by the power plant is higher than that of the fuel cell. The power regulator has the ability to charge the power battery concurrently. Based on the fuel cell stack's maximal power capability, the power regulator is chosen. To stop negative current from entering the fuel cell stack, a diode is needed at the output of the stack. The fuel cell stack may be harmed if a negative current is let to flow, which can cause the battery to reverse phase. The power regulator's switching of the power components causes just a little amount of ripple in the fuel cell stack output current. The fuel cell stack's power output to the load is regulated by the power regulator. To determine the reference current, divide the power command by the battery voltage in proportion to the required power [4].

Efficiency, performance, and reliability must be given top priority in the design of fuel-cell subsystems like the FCCU while costs are kept to a minimum. Infineon provides a wide range of automotive power solutions to help designers meet any difficulties brought on by fuel-cell technology [4]. FCCU is the core control component of fuel cell vehicle, responsible for processing driver input and system operation status signals, such as power demand, system status, vehicle signal input, fault diagnosis, fuel cell temperature and current, etc. Through these signals, the control decision and calculation are carried out, and the control instruction is output to the control unit of each component. The operation of the vehicle basically determines the functions that the controller should achieve.

3. Crucial technologies used in fuel cell vehicles

3.1.Battery technology

A chemical device known as an electrochemical generator or fuel cell directly transforms the chemical energy of fuel into electrical energy. After atomic, thermal, and hydroelectric power, it is the fourth type of power producing technique [5-6]. Figure 2 shows the structure of FCV. Figure 3 is a schematic diagram of a hydrogen fuel cell.

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Figure 2. The construction of FCV [4].

Figure 3. Hydrogen fuel cell [7].

The electrochemical nature of fuel cells makes them similar to conventional batteries in terms of their workings. Two electrodes-a negative electrode, or fuel electrode, and a positive electrode, or oxidizer electrode—along with electrolyte make up its single cell. The difference is that the general battery's active ingredient is kept inside the battery, reducing its capacity. In contrast, the positive and negative electrodes of a fuel cell are essentially catalytic conversion components and do not actually contain active material. Consequently, the fuel cell is a true machine for converting energy, transforming chemical energy into electrical energy. The fuel and oxidizer are externally supplied when the cell is operating to carry out the reaction. The fuel cell can theoretically produce power continuously as long as the reactants are continuously fed and the reaction products are continuously removed [8].

3.2.Motor technology

Due to its superior electromagnetic torque control properties compared to AC motors, DC brushed motors continue to be the primary focus of domestic and international research and development for electric vehicle motors today. However, due to their expensive cost, massive size, and heavy mass, DC motors have only found limited use in electric vehicles [9].

In the field of automobile industry, a motor is widely used to ensure the smooth working performance of automobiles. The motor is a permanent magnet brushless motor. This kind of motor can be divided into square wave driven brushless DC motor system (BLD-CM) and sine wave driven brushless DC motor system according to their different working modes and working principles. These two kinds of motors have their own distinctive characteristics when working, which can be distinguished by industrial technicians. What they have in common is that they have a high power density when working and can generate high power under normal working conditions. In addition, their output efficiency is 6 percentage points higher than that of common AC induction motors.

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Because of the above great advantages, this kind of motor is widely used in the engine of electric vehicles.

As is known to all, AC induction motor is one of the earliest motors used in the automotive field during the use of motor, which has its own irreplaceable advantages. First of all, this kind of motor is very reliable when working, and can easily cope with various complex working conditions. When the vehicle is working, its working environment will often change, which requires the on-board motor to be able to cope with changes in various environments to ensure that the vehicle has good enough safety performance. Secondly, the motor has a simple structure, and can complete the functions required by the vehicle during driving without very complex composition, which is very friendly for vehicle maintenance personnel. In addition, the motor has obvious advantages such as low cost, reliable operation, small torque ripple, low noise, high speed limit, and no position sensor. This motor is used in most electric vehicles produced in the United States and Europe.

The switching reluctance motor (SRM) has the benefits of being easy to use and dependable, operating effectively over a wide speed and torque range, having flexible control, operating in four quadrants, being quick to react, and being inexpensive. SRMs' uses are, however, constrained by drawbacks such significant torque variations, high noise levels, and the requirement for position detectors. Figure 4 is the schematic diagram of DC permanent magnet brushless motor.

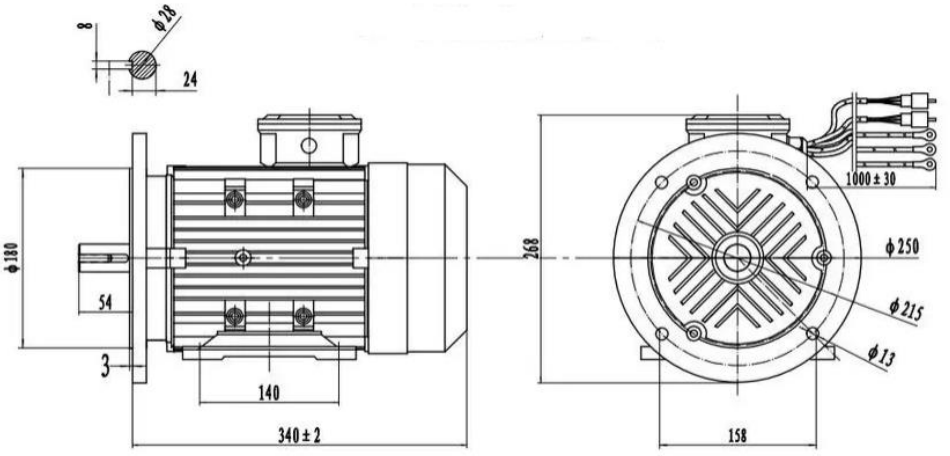

Figure 4. DC permanent magnet brushless motor [8].

3.3.Controller technology

The motor speed control device, which works on the concept of controlling the voltage and current of the motor to achieve the control of motor driving torque and rotation direction, implements the controller technology of variable speed and direction change. Thyristor chopper speed control, currently utilized increasingly frequently in electric vehicles, regulates the motor current by uniformly altering the terminal voltage of the motor to accomplish stepless speed control of the motor. It is also being gradually replaced by various power transistor chopper speed control devices as electronic power technology advances (such as GTO, MOSFET, BTR, and IGBT, etc.). The speed control of electric vehicles will inevitably move toward the use of DC inverter technology as a result of technological advancements and the adoption of new drive motors [10]. Figure 5 shows a brushless motor driven high-voltage controller.

The contactor is used to change the magnetic field's or armature's current direction in the drive motor rotation change control, which makes the control circuit more complicated and less dependable.When using an AC asynchronous motor drive, the control circuit can be made simpler by simply changing the phase sequence of the magnetic field's three-phase current. It is also simpler to handle the braking energy recovery of electric vehicles thanks to the usage of AC motors and their variable frequency speed control technology.

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Figure 5. Brushless motor drive high voltage controller [9].

4. Prospects and disscussion

Moving to the prospects of FCV: Fuel cells currently have the most potential in transportation applications, but also in energy storage, military applications and other fields. The research and development of hydrogen fuel cell vehicles has been widely carried out and put into the market in Japan, the United States, South Korea and other countries. The ownership of fuel cell vehicles in the United States accounts for 50% of the world, and there are 25,000 fuel cell delivery vehicles alone. Japan's Toyota, Honda and South Korea's Hyundai have launched their own fuel cell vehicles. Since the industrialization of hydrogen energy in China started late, the overall level is still behind that of developed countries, so China's hydrogen fuel cell vehicle industry is also in the initial stage, the degree of marketization is low, and some key parts and materials still rely on imports. Although the hydrogen fuel cell vehicle market degree is relatively high in some developed countries, the application degree is generally low due to the purchase quantity limitation.

Global sales rose to 7,500 units in 2019, with China accounting for most of the increase. As of December 2019, the total number of fuel cell vehicles in the world reached 24,132. The number of foreign fuel cell vehicles has reached 17,967. Global hydrogen fuel cell vehicle sales hit a record high in 2019, reaching 10,409 units [5].

According to the data collected, it can be concluded that FCV gradually becomes the focus in various countries. Why does the research on FCV becomes so essential and necessary? According to relevant reports, we can draw the following conclusions: 1. Fuel cell vehicles are more environmentally friendly than fuel vehicles. The only product of fuel cell vehicles in the working process is water, which will not pollute the environment, while the exhaust emissions of fuel cell vehicles will bring many pollutants. 2. Compared with ordinary fuel vehicles, fuel cell vehicles are more conducive to the health of drivers, have less noise, and do not involve the noise of other engines, which can effectively improve the safety during driving. 3. Driving costs can be reduced. Nowadays, the fuel cost of fuel vehicles is gradually increasing, which brings huge costs to people's use of vehicles [6]. As the environment problems are the becoming increasing vital, it is no doubt that countries should spend more on reducing the pollution. Cars which are the needs for most families should be improved since too much green-house gases will cause the global warming.

In conclusion, the FCV is a meaningful product which helps to achieve the sustainable development. People are supposed to have the awareness of energy saving and emission reduction.

5. Conclusion

No action can reverse centuries of unregulated climate change, but shifts in energy use, for example, may be one possibility to try to improve today's climate conditions. For now, however, improving and controlling greenhouse gas emissions may be an effective way to reduce pollution of the climate.

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Although these changes may be small, over time they may have an impact on balancing climate pollution. This will also allow mankind to have a better future, because although it is not possible to eliminate the atmospheric pollution caused by greenhouse gas emissions over a long period of time since the industrial revolution, we are trying to optimize the deteriorating environment and keep trying, in the hope that in the future we can live in a world where we do not have to worry about environmental problems.

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