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Analysis of electric vehicle technology in China and the company BYD

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Energy consumption and environmental pollution are major restrictive conditions impacting sustainable development of Chinese economy, Research and development on vehicles that use alternative energy is thus a priority in China.

Electric vehicles (EV) will reduce the usage of gas, and its related environmental damage. Unlike gas vehicles in which China is far behind in research and technology compared to many other countries, EV development is relatively new to the world in which China has shown great initiative.

This thesis extensively analyzed and reviewed the EV development in China focusing on the advantages and disadvantages of EV; major components of the technology, and obstacles of EV facing while focusing on the company BYD - a leading EV company in China. In hope to explain electric vehicle trends in China and how the company BYD is approaching them.

Keywords	electric vehicle, key technology, characteristic analysis, development strategy.

Contents

1. Purpose and Significance of Electric Vehicle Research

1.1 Purpose of electric vehicle research

China has the largest vehicle ownership and sales. China’s energy consumption is also among the highest in the world. Energy consumption in China grew by 1.3% in 2016. Growth during 2015 and 2016 was the lowest over a two-year period since 1997-98. Despite this, China remained the world’s largest growth market for energy for the 16th consecutive year [1]. High energy consumption has been causing China to be dependent on fuel import consequently, it has caused serious environmental pollution. The development of electric vehicles can reduce China's dependence on oil, improve the status of environmental pollution, and increase international sales of electric vehicles and prompt Chinese economy.

1.2 Significance of electric vehicle research

As Figure 1 indicates, more than 51% of a barrel of oil becomes gasoline. Most of that goes to fuel vehicles. The continuous demand of oil has shifted the focus towards alternative fuels. Also, automobile emissions into the atmosphere and the harm to the human health has become clearer and alarming.

The international community has formed an unspoken consensus towards the development of electric vehicles, developing EV to be the new form of transportation.

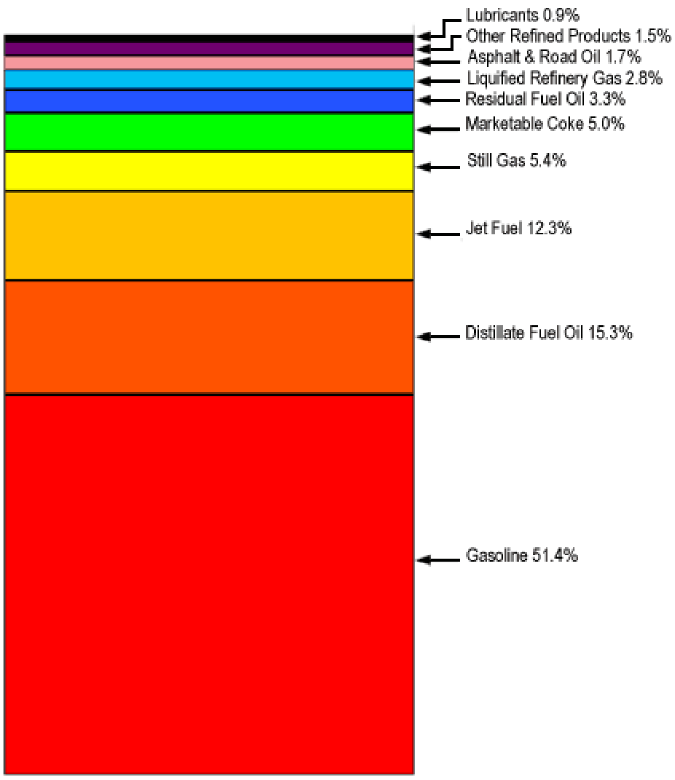

Figure 1: Raw oil distribution

2 Development of electric vehicles

2.1 Development status of electric vehicles in other countries

In 1859 French physicist Gaston Planté invented the lead-acid battery, which in turn makes practical electric vehicles a possibility. (Lead-acid batteries are still used in some electric vehicles today and are used in gas-powered vehicles to help start the engines. However, most modern electric vehicles use lithium-ion batteries. The lead-acid batteries used to start vehicles are still very similar to what Gaston created.)

The definition of all-electric vehicles, zero emissions, low noise, and diverse energy sources of electricity has become the object of competition for researchers across the world. Countries such as the United States, Japan, and Germany already have a considerable capital investment in the field. Research and development of electric vehicles have made great progress. Germany launched a campaign in 2009 to put 1 million electric vehicles on the road by 2020 [2]; the U.S. has ten states that joined the Zero Emission Vehicle (ZEV) program. Meaning automakers are required to maintain ZEV credits equal to a set percentage of non-electric sales. The credit required in 2018 was set to 4.5% (2.5% of total sales). The credit is to be raised to 22% by 2025(8% of total sales).

Norway is now one of the most successful countries in the world in the promotion and application of all-electric vehicles. Every sixth new vehicle purchased in March 2018 was a Nissan Leaf. [3]
In France, the National Interdepartmental Coordination Committee for the promotion and application of electric vehicles was established. Paris and La Rochelle have established relatively complete electric vehicle networks. The vehicle charging station network infrastructure has developed preferential policies to support the use of electric vehicles.

Japan is one of the countries with the most rapid development of hybrid electric vehicle technology and has taken a leading position in the development of hybrid vehicle products. Since the launch of Toyota Prius in 1997 followed by the Honda Insight in 1999, Japan ranked as the market leader with more than 5 million hybrids sold, followed by the United States with cumulative sales of over 4 million units since 1999. The technology of fuel cell electric vehicles is also advanced in Japan, using various fuels such as methanol, natural gas, and hydrogen to react with oxygen or air. The chemical energy of the fuel is converted into electricity. Toyota, the leader in hybrid vehicles, is also preparing to take a lead in hydrogen fuel cells. Toyota plans to launch a new fuel cell vehicle in Japan, the United States and Europe. And betting that this model's annual sales will reach 10,000 vehicles by 2020. In addition, there are Honda and Mercedes-Benz. A fuel cell vehicle being developed by Honda is expected to be on the market. The vehicle is expected to be able to run for about 500 kilometers on a single charge. The sales target set by Honda is to sell 5,000 vehicles in five years. The sales target markets are mainly in Japan, the United States, and Europe.

2.2 Development status of electric vehicles in China

In the Tenth Five-Year Plan period, which are a series of social and economic development initiatives. The Tenth Plan mainly focuses environmental front, the environmental initiative includes the aim to overcome the problems of electric vehicle technology, The Ministry of Science and Technology proposed a “three vertical and three horizontal” electric vehicle R&D strategic plan. Three horizontal refers to electric drive system, power system and auxiliary system; Three vertical refer to all-electric vehicles, hybrid vehicles and hydrogen fuel cell vehicles.

layout for fully deploy key technologies for electric vehicles and established the Electric Vehicle Major Science and Technology Project. This project, through the organization of enterprises, institutions of universities, and scientific research institutions, has concentrated all aspects of its forces on tackling a joint research. The results of R&D are fruitful, and some of the technologies have surpassed the world's highest level. During the Eleventh Five-Year Plan period, based on conscientiously summing up the preliminary research results, the research and development of the electric vehicle power system technology platform and key parts and components were focused on, and the industrialization of large-scale technologies was strengthened.

At present, all-electric vehicles and all-electric passenger vehicles have passed the type certification test of the national quality inspection center, and all indicators meet the requirements of relevant national standards and enterprise standards. In December 2007, the Jiexun HEV developed by Changan Automobile entered the mass production phase. This is the first hybrid vehicle independently developed in China.

China's auto companies have also been investing in hydrogen fuel cell vehicles , but after 2006, almost all automaker brands have withdrawn from research on fuel cell vehicles except for SAIC. At present, research and development projects for fuel cell vehicles are mainly undertaken by universities such as Tongji University and Shanghai Jiaotong University. The reason why auto companies withdraw from research on hydrogen fuel cell vehicles is that hydrogen fuel cells cannot compete with electric vehicles. [4] It is hard to establish infrastructure to refill fuel cells, and the travel distance is way lesser compare to gasoline or electric.

After a decade of experience, electric vehicles in China have begun to enter the stage of industrialization from the stage of research and development. The rising Chinese electric vehicle industry has shown promising results.

In the Twelfth Five-Year Plan outline issued in March 2011, China listed new energy vehicles as a strategic emerging industry. First, it was proposed to focus on the development of plug-in hybrid electric vehicles, all-electric vehicles and fuel cell vehicle technologies, plug-in hybrid vehicle and all-electric vehicle R&D and large-scale commercial demonstration projects and promote industrial applications. In the future, China's electric vehicles could usher in a new round of rapid development.

3 Company BYD

BYD is an automobile company, whose operations include R&D, design, mold manufacturing, vehicle production and sales services. BYD Auto has reached an internationally advanced level in vehicle R&D, mold development, vehicle manufacturing, and its industrial structure is gradually improving. BYD Automotive adheres to the development model of independent brands, independent research and development, aiming to bring their brand international recognition.

BYD is now well established in the field of electric vehicles as well as rechargeable battery industry, and already has the technology and conditions for large-scale commercialization and can develop a more energy-efficient and environmentally friendly electric vehicle product that achieves improved performance and popularity.

3.1 History

Wang Chuanfu founded the company in February 1995. Initially, the company specialized in manufacturing rechargeable batteries, occupying more than 50% of the world's mobile phone battery market. In 10 years it became China's largest and most prominent rechargeable battery manufacturer.

On January 23, 2003, BYD announced that it had acquired 77% of Xi'an Qin-chuan Automobile's shares for 270 million yuan and officially entered the automobile manufacturing industry. BYD Auto sold a total of 506,189 passenger vehicles in China in 2013, making it the tenth-largest selling brand and the largest selling Chinese brand. In 2015, BYD Auto was the bestselling global electric vehicle brand.

4 BYD electric vehicle technology

BYD Auto follows the development path of independent research and development, independent production, independent brands, aiming to transition from dual-mode hybrid vehicles to all-electric vehicles.

The BYD F6DM dual-mode electric vehicle using an ET-POWER iron-powered battery, has achieved safe and stable performance. When fully charged, the vehicle can travel a total distance of 430 km, with a maximum power of 200 kW, a maximum speed of 160 km/h, and a power consumption of 15 kW/h per 100 km.

Picture 1: Example of a BYD EV

The BYD F3DM dual-mode electric vehicle is equipped with a BYD371QA aluminum engine; with a power up to 50 kW, plus a 75 kW motor, the total output power is 125 kW, which achieves a 3.0 L internal combustion engine's power output level. The vehicle achieves the longest continuous driving range of 100 km in the world with the maximum speed of up to 150 km/h. Using both gas and electricity, the total driving range can reach 500 km or more.

There are three types of electric vehicles, namely, all-electric vehicles (BEV), hybrid vehicles (HEV), and fuel cell vehicles (FCEV).

4.1 All-electric vehicle

October 26, 2011, BYD e6 pioneer electric vehicle was officially released. BYD e6 pioneers is equipped with BYD's own researched and developed iron batteries, the vehicle's maximum (rated) power of about 100 horsepower, peak torque of 450N.m, the maximum speed can reach 140 km/h or more. In the absence of air conditioning, the vehicle's driving range is 300 km and the energy consumption per 100 km is about 20 kWh.

All-electric vehicles are motor-driven vehicles. The main difference between all-electric vehicles and fuel vehicles lies in the four major components - drive motors, speed controllers, power batteries, and vehicle chargers.

The speed and starting speed of an all-electric vehicle depend on the power and performance of the drive motor. The range depends on the capacity of the vehicle-mounted battery. The weight of the vehicle-mounted battery depends on which battery is used, a lead-acid, zinc-carbon, or lithium battery. They vary in volume, specific gravity, specific power, specific energy, and life cycle.

4.1.1 Electric drive system

The electric drive system includes electronic controllers, power converters, motors, mechanical transmissions and wheels. Its function is to efficiently convert the electric energy stored in the battery into the kinetic energy of the wheels, and to be able to turn the wheels when the vehicle is decelerated and braked. Kinetic energy is converted into electricity to charge the battery. The latter function is called regenerative braking.

The electric drive mode of an electric vehicle can basically be divided into two types: a motor center drive and an electric wheel drive. A motor central drive system consisting of a motor, a fixed ratio reducer, and a differential. In such a drive system, since there is no clutch and transmission, the mechanical transmission can be reduced in size and quality.

Another kind of arrangement of the central drive system of the electric motor is like that of the front-wheel drive and the front-mounted engine of the fuel vehicle. The electric motor, the fixed speed ratio reducer and the differential are integrated, and the two half shafts are connected to each other. This arrangement is most commonly used in small electric vehicles.

The motor and fixed-speed planetary gear reducer are mounted inside the wheel, without a drive shaft and a differential, which simplifies the drive system. However, the electric wheel driving method requires two or four electric motors, and the control circuit thereof is also more complicated. This driving method has more extensive applications in heavy-duty electric vehicles.

The driving motor of an electric vehicle mainly used a DC motor before the 1990s. It has the advantages of a large driving force when starting acceleration, simple speed control, and mature technology. However, the armature current of the DC motor is introduced by the brush and the commutator. When the commutation is performed, sparks are generated, the commutator is easily abraded, the brushes are easily worn, and they need to be replaced frequently. The maintenance workload is large. The friction loss at the contact part not only reduces the motor efficiency, but also limits the operating speed of the motor.
At present, no commutator DC brushless motor is available. It consists of a motor body, a rotor angle sensor and an electronic switch control circuit. The electronic switch control circuit plays the role of a commutator in an ordinary DC motor. The DC brushless motor has many advantages such as simple structure, reliable operation and the convenient maintenance of the AC motor, and it has the characteristics of high operating efficiency, no excitation loss, low operating cost, and good speed regulation performance. Therefore, its application in electric vehicles is increasing day by day. For example, the BMW EI electric vehicle produced by BMW and the IZA electric vehicle developed by Tokyo Electric Power Co., Ltd. all use a permanent magnet brushless DC motor as the electric drive.

The AC induction motor is widely used in electric vehicles. This is because when the induction motor adopts variable frequency speed regulation, it can cancel the mechanical transmission and achieve stepless speed change, which greatly improves the transmission efficiency. In addition, the induction motor is easy to achieve positive and negative reversal, and the recovery of regenerative braking energy is also simpler. When a squirrel-cage rotor is used, the induction motor also has the advantages of simple structure, robustness, low cost, reliable operation, high efficiency, and maintenance-free.

Another type of AC motor used in electric vehicles is an AC synchronous motor. When the permanent magnetic material is used to replace the field winding of the synchronous motor, the permanent magnet synchronous motor can eliminate brushes and slip rings, and there is no copper loss of the field winding. It is even more efficient and smaller than the induction motor.

Switched reluctance motors are recognized as a very promising electric vehicle drive motor. Its stator and rotor are made of ordinary silicon steel lamination. There are neither windings nor permanent magnets on the rotor. Only concentrated windings are wound on the stator. Switched reluctance motors have the advantages that ordinary DC motors and AC motors cannot match:

1. Simple, sturdy and durable structure, low cost, can work under extremely high speed, can adapt to high temperature and strong vibration working environment;
2. Starting torque large, low-speed performance;
3. Wide speed range, flexible control, easy to implement a variety of special requirements of the torque - speed characteristics;
4. High efficiency in a wide range of speed and power.

Power converters for electric vehicles are used for DC-DC conversion and DC-AC conversion of different frequencies. DC-DC converters, also known as DC choppers, are used in DC motor drive systems. The two-quadrant DC chopper converts the DC voltage of the battery to a variable DC voltage and reverses the regenerative braking energy. DC-AC converters, commonly referred to as inverters, are used in AC motor drive systems, which convert the DC power of a battery into AC power with adjustable frequency and voltage. Electric vehicles generally use only voltage-input inverters because of their simple structure and bidirectional energy conversion.

4.1.2 Power system

The power system includes a power source, an energy management system, and a charger. Its function is mainly to provide the motor with drive power, monitor the power usage, and control the charger to charge the battery.

Power supply is a factor that restricts the development of electric vehicles. As a power source for an electric vehicle, it should have high specific energy and high specific power to meet the requirements of the vehicle's power and driving range. In addition, it should also have the same life cycle, high efficiency, low cost and maintenance-free features as the whole of the vehicle.

The current power supply for electric vehicles is mainly batteries, followed by fuel cells. A battery is an energy storage device, and energy storage is achieved through external charging. A fuel cell is an energy generating device that generates electrical energy through a chemical reaction. The battery technology is mature, the price is reasonable, and the fuel cell is the most promising electric vehicle power source.

The main performance indicators of the battery are:

1. Specific energy - the amount of energy that a unit of battery can store (W·h/kg), which is an indicator for evaluating the quality and mileage of an electric vehicle;
2. Energy density - the stored power (W·h/L), which affects the size of the battery;
3. The power—the power output per unit battery mass (W/kg), is an evaluation of the acceleration, climbing ability, and maximum speed of the electric vehicle Indicators;
4. Power density - the power output per unit volume of the battery (W/L);
5. Life cycle - battery charge and discharge once as a cycle, life cycle that can be completed before the replacement of the battery cycle.

The short life cycle will increase the maintenance cost of electric vehicles.

Lead-acid batteries are widely used in electric vehicles. The main reason is that the technology is mature, the price is low, and the reliability is good. The single-cell rated voltage is high (2.0 V). In addition, large output currents and good performances in high and low temperature are suitable for electric vehicles. However, lead-acid batteries have the disadvantages of low specific energy, long charging time, and short service life.

Ni-Cb battery has high specific power, high specific energy, fast charging, long service life, strong anti-current impact capability, wide operating temperature range (-40°C～85°C), and large discharge current range, and small changes in internal voltage. Thus, it has become an attractive power sources for electric vehicles. However, the production cost is high (about 2 to 4 times that of lead-acid batteries), the single-cell rated voltage is only 1.2 V, and the heavy metal cadmium has carcinogenicity, which limits its wide application in electric vehicles.

Nickel-metal hydride (Ni-MH) batteries have many of the same characteristics as Ni-Cd batteries, but because they are cadmium-free, they do not have the problem of heavy metal contamination and are called "green batteries." The cost of mass production is about four times that of lead-acid batteries. The nominal voltage of the Ni-MH battery cell is 1.2 V, and its negative electrode is a hydrogen storage alloy after hydrogen absorption treatment. The positive electrode is nickel hydroxide and the electrolyte are a KOH solution.

The sodium-sulfur (Na-S) battery has a high specific power and specific energy, but its high operating temperature, coupled with the activation and corrosion of sodium, must be structurally robust and safe. Na-S battery uses molten sodium as the negative electrode, molten sulfur as the positive electrode, and ceramic β-Al_2O_3 as the electrolyte, and acts as a separator between the ion-conducting medium and the molten electrode to avoid self-discharge of the battery.

Lithium-ion (Li-Ion) batteries have developed rapidly since the advent of the early 1990s. Although lithium-ion batteries are still in the development stage, lithium-ion batteries are used in electric vehicles such as Nissan FEV, Nissan Prairic Joy and Altra. It has the advantages of high single-cell rated voltage, high specific energy and energy density, and long service life. The disadvantage is its high self-discharge rate.

The energy management system is composed of sensors, control units, and input/output interfaces of voltage, current, and temperature. Its functions are as follows:

1. It detects the terminal voltages and temperatures of individual battery cells in the battery pack of an electric vehicle and the charge of each battery cell, and discharge current;
2. It predicts the remaining power of the battery pack and the mileage of the electric vehicle;
3. When the battery needs to be charged, there is a timely alarm to prevent the battery from over-discharging and affect its service life;
4. When the battery pack is charged, the energy management system, according to the detected data of each cell, determines the charge state of each cell, and controls the charging process of the charger to ensure that each cell is evenly charged so that it does not overcharge or undercharge.
5. Distribute the battery energy reasonably, to achieve energy-saving purposes, for example, when the lead-acid battery is used as the main power supply for electric vehicles, when the vehicle starts and climbs, temporarily turn off the air-conditioning and other power-consuming appliances, so that the battery discharge current is not too large. Which explain why the radio is turned off during vehicle ignition.

4.1.3 Auxiliary system

The auxiliary systems include auxiliary power sources, power steering systems, navigation systems, air conditioners, lighting and defrosting devices, wipers, radios, and the like. With these auxiliary devices, the vehicle's maneuverability and occupant comfort are improved.

Most of the auxiliary equipment in the electric vehicle auxiliary system is basically the same as that of a fuel vehicle, such as an auxiliary power source, an air conditioner, a power steering system, a navigation system, the wipers, a radio, and a lighting and defrosting device.

The auxiliary power source of an electric vehicle is mainly composed of an auxiliary power source and a DC-DC power converter, and its function is mainly to provide power to a power steering system, an air conditioner, and other auxiliary equipment.
The difference between the auxiliary system of the electric vehicle and the auxiliary system of the fuel vehicle is that the auxiliary power source of the fuel vehicle is charged by the engine-driven alternator, and the auxiliary power source of the electric vehicle is charged by the main power source through the DC-DC power converter.

The various systems are arranged in various ways on electric vehicles. This is because on electric vehicles, energy is transmitted through flexible wires instead of through rigid couplings and shafts. Therefore, the arrangement of various systems or components of electric vehicles has Great flexibility. For example, a motor front, front-wheel drive electric vehicle. The charger charges the battery placed at the rear of the vehicle via the charging interface at the front of the vehicle. While the vehicle is running, the battery supplies power to the motor via the controller. The signal from the accelerator pedal is input to the controller and the controller adjusts the motor output torque or speed. The torque output by the motor drives the wheels through the vehicle drive system.

4.2 Hybrid vehicles

2014 BYD Qin sold 14,747 units throughout the year, becoming the annual sales champion of new energy vehicles, and electric vehicle electrification is steadily advancing. On this basis, BYD proposed the "542 Strategy," which will set new standards for performance, safety, and fuel consumption for new energy vehicles.

In January 2015, BYD announced its first 542 strategic model — Tang released for pre-order. Tang is the world's first three-engine (three power source) four-wheel drive dual-mode (free to switch between hybrid and all-electric mode) SUV. The three engines reach 100 km/h within 5 seconds. Electronic drive technology to subvert the traditional mechanical full-time four-wheel drive era, bringing efficient transmission, speed response and higher security. Tang offers dual-mode switching, all-electric short-distance drive, mixed long-distance drive with a fuel consumption of 2 liters per 100 kilometers. And as a dual-mode SUV, Tang also provided consumers with more choices on plug-in hybrid models and opened a new growth point for BYD's vehicle sales.

Hybrid vehicles have two different power sources. These two kinds of power sources can work together or work separately for fuel economy and environmental protection by minimizing fuel consumption and exhaust emissions through combination. Its energy efficiency increased from the original 60% to 70% to more than 95%, thus saving nearly half of the fuel, and has made great progress in reducing engine noise and exhaust gas pollution.

Hybrid vehicles use the control system to combine the two types of power sources, which not only has the advantages of the traditional vehicle's dynamic driving range, but also has the advantages of energy-saving and environmental protection for electric vehicles. Under the heavy load condition of the vehicle, the electric motor can supplement the required torque of the vehicle. Under the small load condition, the motor can absorb and store the excess energy, which can greatly reduce the fuel consumption of the vehicle and reduce the amount of pollutants to be discharged. In terms of environmental protection, hybrid vehicles only reduce the emission of pollutants and do not really achieve zero emission. However, hybrid vehicles are better in terms of power and economy, and they are in line with people's desires for new energy vehicles in reducing pollution. The requirements can ease the problems between the huge demand of the automotive market and environmental pollution and resource consumption. Therefore, the development of hybrid vehicles has practical significance today.

At present, the dual-mode of most hybrid vehicles is of different type. Compared with the use of other energy sources, hybrid vehicles have very practical significance in promotion: they are mature in technology and prices are close to the market. Therefore, this kind of vehicle has already occupied a certain proportion in the vehicle market, in actual use also can satisfy the market demand more than other new energy vehicles. However, the high cost of production R&D remains an urgent problem to be solved. In the process of driving a hybrid vehicle, two different power devices need to be constantly changed. Because of different energy supplies, the technical requirements for these two systems are relatively high. This also determines that the production cost of hybrid vehicles is higher than that of ordinary gasoline and diesel vehicles, therefore the market price is higher.

Hybrid vehicles are divided into three types: series, parallel, and series-parallel, depending on how the internal combustion engine and the motor are connected. Series hybrid vehicles are the simplest. Internal-combustion engines drive generators to generate electricity, and electric power is sent to the motor to drive the vehicle. If there is excess power, it is used to charge the battery. When high power output is required, the generator and battery supply power to the motor at the same time. Obviously, series hybrid vehicles have the same driving range as fuel vehicles.

The parallel hybrid vehicle adopts two independent driving systems of internal combustion engine and electric motor. The internal combustion engine can drive the vehicle alone, the electric motor can also drive the vehicle alone, and the internal combustion engine and the electric motor can also jointly drive the vehicle. When the output power of the internal combustion engine is greater than the power required to drive the vehicle or regenerative braking, the electric motor works in the generator state and will be redundant. The energy is converted into electrical energy to charge the battery. Obviously, parallel hybrid vehicles can reduce vehicle exhaust emissions and fuel consumption.

Serial-parallel hybrid vehicles have both series and parallel types, but they have complex structures and high costs.

In addition to traditional automobiles, the industry has long been looking forward to, and the world’s first new energy dual-mode electric vehicle F3DM that does not rely on professional charging stations was officially launched on December 15, 2008. This dual-mode vehicle integrates many top-notch high-tech technologies in automotive manufacturing, battery technology, motor systems, and automotive electronics technology, and is a model for energy conservation, environmental protection, fashion, and technology. As an example of a hybrid vehicle, a drive system of a new type of parallel hybrid vehicle adopts a two-degree-of-freedom planetary gear mechanism as a speed reducer. When the vehicle is fully accelerating, the internal combustion engine and the electric motor work together to provide the necessary power for the vehicle. When the vehicle is running at constant speed or light load, the required power of the vehicle is mainly provided by the electric motor, and the electric motor is decelerated by the two-degree-of-freedom planetary gear mechanism. The internal combustion engine only provides the minimum torque and the minimum power. When the vehicle runs in the suburbs, only the internal combustion engine works, the motor does not work, and the ring gear of the planetary gear mechanism is locked. Currently, the planetary gear mechanism has only one degree of freedom.

Volkswagen has installed a diesel motor drive system on Golf models. A 6 kW compact induction motor is installed at the position equivalent to a diesel flywheel, and an automatic steering clutch is mounted on the diesel engine side and the transmission side. When the clutch on the diesel engine side is in a disengaged state, the vehicle is driven by electric power. When the vehicle is driven by a diesel engine, the clutch on the diesel engine side is engaged. Currently, the rotor of the induction motor acts as a take-off wheel, and the motor also serves as a starter and an alternator.

Since the two power units are respectively used for the respective optimum working conditions, the fuel economy of the hybrid drive system is very good, and the comprehensive emission level is very low. Compared with Golf models that are generally equipped with diesel engines, diesel consumption is reduced by 62%, harmful emissions are reduced by 40% to 60%, and charging of batteries at night requires 12 to 16 kWh.

4.3 Hydrogen fuel cell vehicles

A fuel cell is a device in which a fuel and an oxidant directly convert their chemical energy into electrical energy through an electrode reaction. Fuel cell chemical reaction process will not produce harmful products, so the fuel cell vehicle is a pollution-free vehicle, fuel cell energy conversion efficiency is 2 to 3 times higher than the internal combustion engine, so from the energy use and environmental protection, fuel cell vehicle is an ideal vehicle[5].

The working principle of a hydrogen fuel cell vehicle is to generate electricity through hydrogen: Pure hydrogen is injected into a tank and mixed with oxygen in the air to produce water, which also produces electricity. The generated electric energy drives the electric motor to work and then drives the mechanical transmission structure of the vehicle. Fuel cell vehicles are divided into two types: energy storage systems for vehicle-mounted hydrogen storage tanks and vehicle-mounted hydrogen (hydrogen) generation systems. The former is simple to use. Similar to a natural gas vehicle, the hydrogen storage tank can be replaced after the hydrogen in the hydrogen storage tank is used up; the latter is more complex, and the vehicle must be equipped with a fuel tank to reserve fuel such as gasoline, methanol, and ethanol, through the modification. The device converts fuel into hydrogen as an energy source for the fuel cell stack.

Individual fuel cells must be combined into fuel cell stacks to obtain the necessary power to meet the requirements of vehicle use. The fuel cell does not need to be charged. As long as the fuel and oxidant are continuously supplied from the outside, continuous and stable power generation can be achieved. The fuel for the electric vehicle fuel cell is hydrogen and methanol, and the oxidant is air. Fuel cells have the advantages of high specific energy, long service life, low maintenance workload, and continuous high-power supply. In addition, fuel cell electric vehicles can achieve the same driving range as fuel vehicles.

According to different electrolytes, fuel cells can be classified into five types: alkaline fuel cells, phosphoric acid fuel cells, proton exchange membrane fuel cells, molten carbonate fuel cells, and solid oxide fuel cells. Suitable for electric vehicles are alkaline fuel cells and proton exchange membrane fuel cells. In a fuel cell, a working substance of fuel as a negative electrode causes an oxidation reaction at a negative electrode; oxygen (air) as a working substance of a positive electrode causes a reduction reaction at the positive electrode. In an alkaline fuel cell, hydrogen and oxygen (air) are respectively adsorbed on an electrode made of activated carbon, and two electrodes are placed in the KOH electrolyte. If an external circuit is connected, current flows through the load.

Using nickel as a positive electrode catalyst, lithium nickel oxide as a negative electrode catalyst can accelerate the reaction process of the battery. The proton exchange membrane fuel cell uses a solid membrane as the electrolyte, the membrane is sandwiched between positive and negative electrodes, and platinum is used as a catalyst for the electrode reaction.

The use of proton exchange membrane fuel cells as power supplies for electric vehicles has the following advantages:

1. Among all fuel cells, the specific power and power density of proton exchange membrane fuel cells are the highest, and in the case of the same output power, the volume is minimal;
2. The temperature is low, the starting time is short;
3. The only liquid in the battery is water, to avoid the corrosion effect;
4. The solid electrolyte is used, so the problem of electrolyte evaporation, overflow and the like does not occur. The disadvantage of proton exchange membrane fuel cells is that the internal resistance is slightly larger, and precious metal platinum is used as the electrode catalyst.

Cells that use methanol are called direct methanol fuel cells or DMFCs. The reason for the development of direct methanol fuel cells is that the sources of methanol are abundant, the production costs are low, and they are easy to store, transport, and sell, making them easy to use in electric vehicles.

The fuel cell vehicle is an ideal power system without the engine's high-temperature combustion and energy loss. However, some technical problems have not yet been solved, such as the size and weight of each unit of power, the maximum speed and distance. R&D and production costs are relatively high, and there are no supporting facilities capable of providing fuel. Therefore, it needs a long process to be widely applied.

Fuel cell vehicles are mainly automobiles driven by electric motors, and the motor's power derives from the currents obtained through the complex chemical reactions of fuels such as methanol and hydrogen. The fuel cell does not burn during the chemical reaction and does not generate harmful substances. Therefore, the fuel cell-powered vehicle is a pollution-free vehicle. In addition, one of the most significant advantages of fuel cells is their high energy conversion rate, which is two to three times higher than that of common internal combustion engines. Therefore, regardless of the effective use of energy, or considering environmental protection, the fuel cell as an energy vehicle is an ideal type of vehicle.

Hydrogen fuel cell vehicles are recognized as the best way to solve the problems of oil consumption and environmental pollution. All countries are working hard to develop hydrogen fuel cell vehicles, which is the future direction of the automotive industry.

Hydrogen fuel cells can convert chemical energy into electrical energy that is both efficient and clean, with more advanced technology than conventional engines. Hydrogen is used as a carrier for hydrogen fuel cell energy. Hydrogen can be obtained in the same way as electric energy. It can be obtained by converting various primary energy sources and achieve the purpose of protecting the environment and saving petroleum resources.

The use of hydrogen fuel cells as an energy vehicle is the most ideal solution for new energy vehicles. Hydrogen fuel cell vehicles have many advantages, such as high efficiency, no pollution, low noise, and many other advantages that traditional energy vehicles do not have. Because hydrogen can be easily extracted from many substances and can be regenerated, it is the ultimate alternative energy that is most likely to be industrialized. Of course, the difficulty in production technology and industrial promotion is also very large. The biggest problem is the storage technology of hydrogen, which requires deeper research and development. Hydrogen is used as a fuel in automobiles, and its storage must meet the standards for normal driving.

However, hydrogen is bulky at normal temperatures and has flammable and explosive characteristics in the air, so it possesses high risk. Research shows that for hydrogen to be liquefied, it needs to reach a minimum of -253°C. Hydrogen also has a characteristic that hydrogen can adhere to metals like sponges and can be released under appropriate conditions. It is important to reach a high weight ratio of fuel to fuel tank. One to six can be achieved. In addition, this hydrogen storage method must also use liquid nitrogen to maintain the adsorbed metal at a low temperature of -198°C. When the vehicle is running, to release hydrogen from the metal hydride, it requires temperature above 300°C. Both extreme temperature conditions cannot be effectively controlled in ordinary vehicles. In a case of leakage, a very dangerous situation would be created.

5 Characteristics analysis and technical evaluation of electric vehicles

5.1 All-electric vehicle

The advantages of electric vehicles are as follows:

1. No exhaust gas is emitted during driving, so electric vehicles can be referred to as "zero-emission polluting vehicles."
2. High energy efficiency when comparing the total energy efficiency of electric vehicles and gasoline vehicles.
3. Vibration and noise are small, and the inside and outside of the cabin are very quiet.
4. The structure is simple, easy to use and maintenance.

Electric vehicles currently have the following shortcomings:

1. The mileage that can be driven on one charge is shorter compare to gas vehicles.
2. High cost. The high cost of batteries and motor controllers is the main reason for the high cost of electric vehicles. In addition, battery life is short and depreciation costs are high.
3. The charging time is long and generally takes 6 to 10 hours.

6 Comparison of electric vehicles and internal combustion engine vehicles

Electric vehicles refer to vehicles powered by electricity. Electrical energy is stored in a battery to drive the motor, which is the basic form of electric vehicle. There are many sources of electric energy. The ideal electric vehicle's electric energy should come from wind energy, solar energy and or some other source of renewable energy.

The current problem of electric vehicles is that the high cost of the battery leads to high cost of the vehicle, the battery has a long charging time and the interval between charges is short, the energy density is low, and the battery life is short. Therefore, the vehicle has a short continuous mileage. However, the mature technology of pure electric vehicles is an important long-term development direction of China's new energy vehicles.

The public ultra-fast charging station is an important infrastructure part for the commercialization of all-electric vehicles. A well implemented infrastructure is important for the commercialization of all-electric vehicles. Its importance with its shortcoming and successes can be observed in Europe and the United States where the effect can be observed.

An additional problem is that the cable connector between the charger and the vehicle battery must be standardized to form classification of the elements (the battery types, voltages, charging rates). Otherwise, the all-electric vehicles and the public ultra-fast charging stations would fail to connect and be of use to each other.

Public charging stations, special cables, cable connectors, and billing and charging systems are four components of all-electric vehicle and other large charging station consumer industry that are new parts for the automotive industry and require industrial production chain.

6.1 Hybrid vehicles

Compared with pure electric vehicles, hybrid vehicles have the following advantages:

1. While using hybrid power, the internal combustion engine can provide the base load needed power and it can also be complemented with the electrical power when under heavy load. While under low load, the combustion engine can charge the battery without loss of performance.
2. Because of the battery, energy of braking, downhill drive, and idling can be easily recovered.
3. In the bustling urban area, the internal combustion engine can be shut down and driven by the battery alone to achieve "zero" emissions.
4. With the internal combustion engine, the problems encountered in all-electric vehicles such as air conditioning, heating, and defrosting that consume large amounts of energy can be easily solved.
5. You can use the existing gas station to refuel, without having to invest in new infrastructure again.
6. The battery can be kept in a good working condition without overcharging or over discharging, prolonging its service life and reducing costs.

Compared with pure electric vehicles, hybrid vehicles have the following disadvantage:

1. Long-distance high-speed driving basically cannot save fuel.

Hybrid vehicles use two types of energy to work together. They have high energy utilization efficiency. They are driven by electric energy at low speeds in the city. The emission of exhaust gas contains relatively few harmful substances. Plus, current hybrid vehicles are technically mature, and, fundamentally, the shortcomings of short driving range of all-electric vehicles have been solved, and the emissions of hybrid vehicles have been less polluting, making them more environmentally friendly. While hydrogen fuel cell technology has not yet reached full maturity, it can be used as the main category of new energy vehicles.

6.2 Hydrogen fuel cell vehicles

Compared with all-electric vehicles, hydrogen fuel cells have unparalleled advantages, not only they are clean, but also light weight, fast filling. For example, for a vehicle to have a range of 400 kilometers, it only needs 50 kW of fuel cell stack, about 5 kg of hydrogen added, and the same all-electric vehicle can drive for 400 kilometers. The required lithium battery weighs about 700 kg.

At the same time, hydrogen fuel cells can also solve the problem of long charging time for all-electric vehicles.

Compared with internal combustion engines, hydrogen fuel cells have the following advantages:

1. The product of the chemical reaction of the hydrogen fuel cell is water only and does not produce any contaminants.
2. Less moving parts, reliable work, and low noise.
3. There is no burning process, chemical energy is directly converted into electrical energy, and thermal efficiency is high.
4. Light weight. A fuel cell of 75 kW has the mass of 70 kg, but the same power engine could have the mass reach 360 kg.

Disadvantages:

Hydrogen fuel cells are currently technically immature and costly. The problem to be solved is the storage and transportation of hydrogen fuels. In addition, the preparation of hydrogen fuel is also a difficult problem. The preparation of hydrogen fuel requires the electrolysis of water or the use of natural gas, so it still needs to consume large amounts of energy. Unless the energy used is produced by nuclear power, it cannot fundamentally reduce carbon dioxide emissions.

The biggest problem that hydrogen fuel cell vehicles currently face is the cost and service life of fuel cell stacks. If the power of 100 watts is equivalent to a 1.8 liter displacement of a hydrogen fuel cell vehicle, the cost of a hydrogen fuel cell stack alone is close to one million RMB (roughly 13,000 Euro); and hydrogen fuel cell stacks tend to shorten the service life in frequent high-low-speed rotations. In addition, the source of hydrogen is also a problem.

The cost of hydrogen production is higher than that of oil refining and power generation. In 2007, SAIC took a stake in Xinyuan Power, a company specializing in automotive hydrogen fuel cell systems. In hydrogen fuel cell vehicles jointly developed by SAIC and Xinyuan Power, an extended range fuel cell vehicle is being developed. All-electric drive mode for short-distance driving, hydrogen fuel cell stack power generation for long-distance. The purpose of this is to solve the problem of cost and service life. Because all-electric is used for short distances, the fuel cell stack is only used for long distances. Therefore, the power of the fuel cell stack can be reduced, thereby reducing the costs. At the same time, the fuel cell is used only when it is running at a high speed in the long distance, and the high and low speed rotation impact on fuel cell stack life is also reduced.

From a long-term perspective, hydrogen fuel cells have the characteristics of low pollution, high energy efficiency, and "zero emissions". They are the most ideal clean-vehicle technologies and can be used as the long-term goals for new energy vehicles.

7 Conclusion

Based on the above analysis, China's new energy vehicles should use "hybrid power-electricity-hydrogen fuel cells" as the main target of the medium and long-term development of the technical route. In different stages of development, there must be plans for the large-scale development of the new energy automotive industry technology. In addition, the requirements for automotive technology are different in different transportation fields. All-electric vehicles are suitable for public transportation and are an important addition to natural gas vehicles and DME automobiles as a new energy vehicle technology in the public transport field. It is worth noting that the advancement of technology in China's new energy automotive industry is a dynamic process. As technological innovation, industrialization, and factor conditions continue to change, China's new energy vehicle industry will need to make constant adjustments to use the industrial technology advancements.

By then, if the technology is mature, China will able to completely phase out gasoline as a fuel. Combining that target with the existing energy resources in China and considering the development trend of international automotive technology, it is expected that around 2025 the number of ordinary gasoline vehicles on the road in China will be reduced by about half. The first replacement of traditional vehicles will be advanced diesel and gas vehicles. Afterwards new energy vehicles and bio-fuel vehicles will make a solid step toward improving the environment and reducing energy consumption even further.

References

[1] The BP Statistical Review, Statistical Review of World Energy [internet], 2016, [cited 2018 May 02]. Available from: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

[2] Moulson, Geir. German government: 1 million electric vehicles by 2020[internet], [cited 2018 May 02]. Available from: http://abcnews.go.com/Business/german-government-million-electric-vehicles-2020/story?id=8364933

[3] NTB. Hver sjette nye bil som ble kjøpt i mars var en Nissan Leaf,[internet], 2018, [cited 2018 May 02]. Avaliable from: https://www.tu.no/artikler/hver-sjette-nye-bil-som-ble-kjopt-i-mars-var-en-nissan-leaf/433984

[4] Shahan, Zachary. Why hydrogen fuel cell vehicles are not competitive, [internet], [cited 2018 May 02]. Available from: http://energypost.eu/hydrogen-fuel-cell-vehicles-competitive-hydrogen-fuel-cell-expert/

[5] C. E. (Sandy) Thomas, Ph.D. Fuel Cell and Battery Electric Vehicles Compared, [internet], [cited 2018 May 02]. Available from: https://www.energy.gov/sites/prod/files/2014/03/f9/thomas_fcev_vs_battery_evs.pdf