Hydrogen Powered Engine and its Applications

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Abstract. Electric vehicles are very popular in environmental discussions. Major car manufacturers around the world have successively introduced electric vehicles such as the BMW i Series, Mercedes-Benz EQ, etc. In the future, the driving form of automobiles should be closely linked with electric power. Electric vehicles have lower emissions compared to fossil fuel cars, lower driving costs, are more suitable for household use, and feature higher levels of technology. There are still some challenges for electric vehicles to completely replace all the fossil fuel cars. For example, electric vehicles have a short driving range and a very long charging time, causing drivers range anxiety. Electric vehicles perform poorly in extreme environments. Temperature can significantly affect the performance of electric vehicles. Too high and too low temperatures can further shorten the range of electric vehicles. This hinders the development of electric vehicles. Although electric vehicles face these challenges, they are more suitable than fossil fuel for normal families in city to use at this moment.

Keywords: Electric vehicle; fossil fuel vehicle; future development.

1. Introduction

There are two types of electric vehicles (EV): fully electric and hybrid. This essay will focus on fully electric vehicles (EV). EVs are typically powered by an electric motor with a lithium-ion battery. They convert chemical energy into the kinetic energy of cars, emitting no emissions in the process. On the other hand, fossil fuel vehicles, commonly used for family purposes, usually run on gasoline with a spark-plug ignition engine. Burning fuel to generate power for vehicles and emitting exhaust gas is harmful to the environment. Obviously, EVs are more environmentally friendly.

EVs have a lithium-ion battery, typically around 70 kWh. The actual range is usually between 150-300km, while some EVs designed for spacious purposes can run over 500 km in a single cycle [1] This range is sufficient for daily commuting for a week. Due to the characteristics of EVs, the slower the vehicle, the more energy it saves. Conversely, driving at high speeds requires more energy because the electric motor needs high current to maintain the rotation speed of the wheels. In city driving scenarios, typically around 60 km/h, the electric motor experiences a lighter load and requires lower current, resulting in less energy needed for city driving.

To control noise in the city, EVs may be a better choice. When EVs are at rest, they make nearly no sound, as the noise is produced by the cooling fans instead of the motor. However, a fossil fuel engine needs to stay idle when the car is at rest, such as waiting at a traffic light, generating nearly 56 dB of noise, while EVs produce only 47dB [2]. This may help reduce slight noise pollution.

EVs usually have a faster response to the driver. This is because the power transfer from the motor to the wheels is very fast and direct, resulting in minimal energy loss as EVs do not need to switch gears during driving. In contrast, there is around 100 hp loss in power transmission in fossil fuel vehicles, leading to lower energy efficiency compared to EVs. Drivers may have better driving experience with EVs, as they offer higher acceleration, ensuring that power is always readily available for the driver.

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

Some cities have started deploying hydrogen fuel cell uses and freight vehicles to reduce pollutant emissions in the city. Hydrogen energy can serve as an energy storage medium, converting excess renewable energy sources. For example, the solar energy, wind and so on, into hydrogen for storage,

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

2. Operating principle

2.1. Fossil fuel vehicle (Spark-plug ignition engine)

The Energy source is Gasoline. The first process is intake shown in Fig. 1, where the piston moves down to the bottom dead center, the intake valve opens, and the fuel-air mixture enters the cylinder. Fig. 2 shows the second process of compression, where the piston moves up compressing the mixture, increasing temperature and pressure in preparation for combustion. The third process is combustion shown in Fig .3, where the spark plug ignites the mixture, driving the piston down to generate power. The fourth process is exhaust, where the piston moves up due to inertia, the exhaust valve opens, and the exhaust gases are emitted.

The output power of a four-stroke engine is influenced by multiple factors such as intake volume, cylinder capacity, compression ratio, air-fuel ratio. When any of these factors fail to reach the ideal state, it will lead to a decrease in the output power of the four-stroke engine [3].

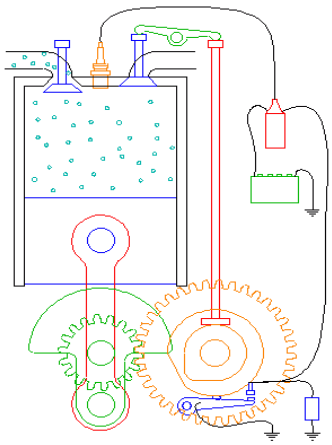

Fig 1. Intake schematic diagram.

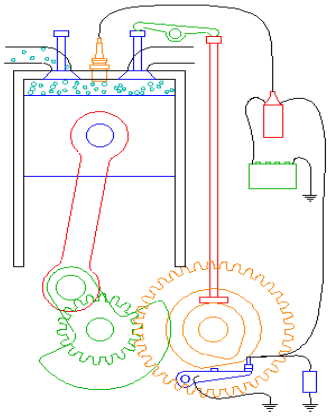

Fig 2. Compression schematic diagram.

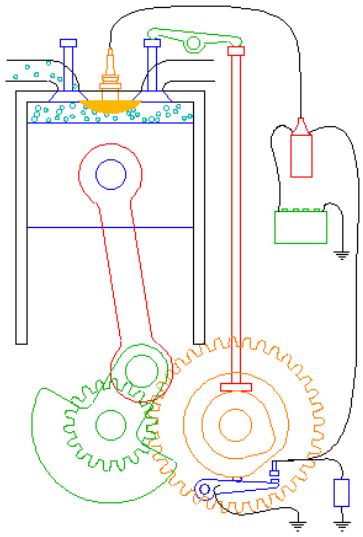

Fig 3. Combustion schematic diagram.

2.2. Electric vehicle

2.2.1. Electric motor

Its Energy source is Lithium-ion battery. Currently through the wire, the wire produces magnetic fields to attract or repulse the magnet surround the motor to produce torque. In this process it takes a much shorter time than a four-stroke cycle. Therefore, EV has faster acceleration than fossil fuel cars. Most electric vehicles use permanent magnet synchronous motors, which offer the advantage of higher power density. And the permanent magnet motor structure is shown in Fig. 4. This type of motor is smaller and lighter in volume and weight compared to other types of motors at the same output power [4].

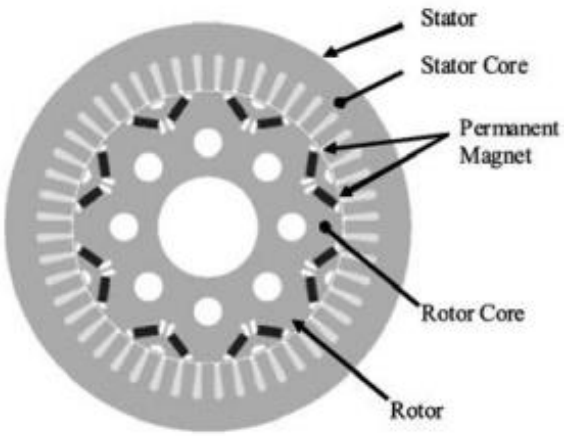

Fig 4. Permanent magnet motor structure.

2.2.2. Switched reluctance motors (SRM)

Switched reluctance motors shown in Fig. 5 are also one of the motor choices for electric vehicles. Their advantages include simple and robust structure, lower requirements for electronic control technology, excellent torque, and acceleration performance. However, the disadvantages include high noise and unstable torque, which greatly affect driving comfort. Therefore, this type of motor is less commonly used in electric vehicles. The performance of SRM see Fig.6 [5].

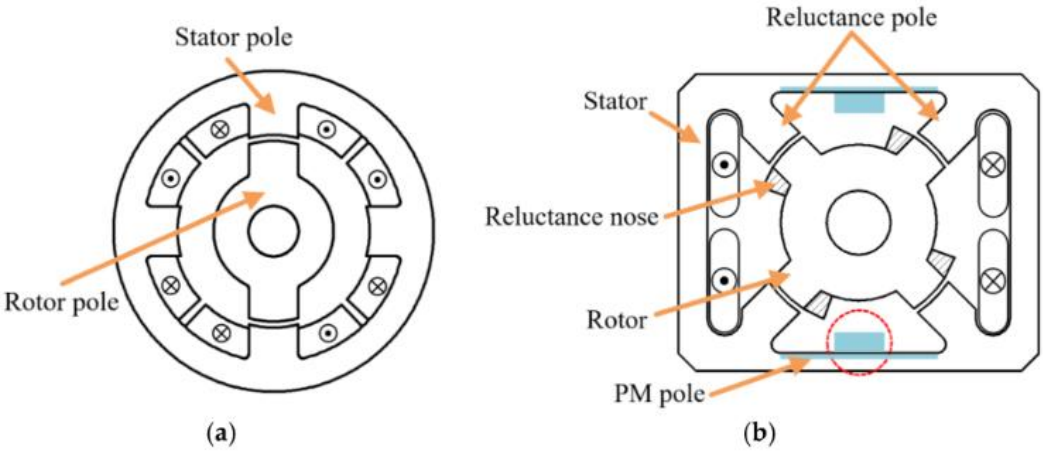

Fig 5. Switched reluctance motors structure.

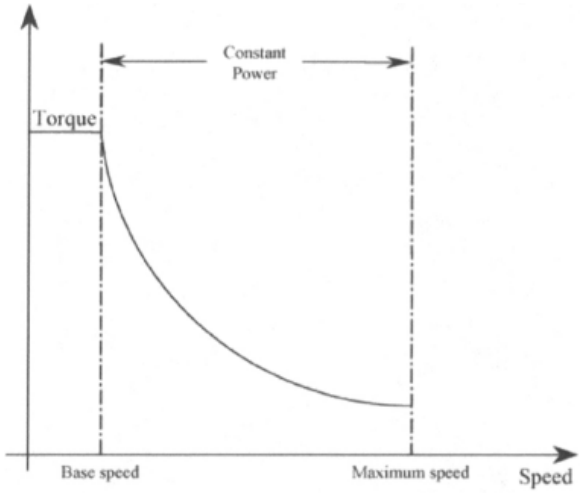

Fig 6. Switched reluctance motors on an electric vehicle [5].

2.2.3. Brushless DC motor

In a brushless DC motor, the stator is in the middle and the rotor is on the outside. This design eliminates the need for brushes to switch the current, improving the motor's efficiency and reducing energy loss from brush friction on the rotor. The compact structure saves chassis space, allowing for larger battery capacity, making it a viable motor choice for electric vehicles. However, the drawbacks of brushless DC motors include greater weight, which increases the overall vehicle weight and affects maneuverability. Additionally, maintenance costs are higher compared to permanent magnet synchronous motors due to their higher technical complexity. This could lead to higher failure rates and increased total cost of ownership.

2.2.4. Control methods

Electric motor control methods are divided into two methods, vector control and direct torque control [6].The performance of vector control depends on accurate detection of vector magnitude and angle. Incorrect data can lead to torque control failure, affecting driving operations. The optimal inverter switching mode for direct torque control maintains torque and flux within the hysteresis band, making direct torque control easier to apply in electric vehicles with better compatibility. It can simultaneously maintain transient and steady-state operational stability.

2.3. Summary

EVs have faster acceleration than fossil fuel cars due to their operating principle. Faster acceleration in EVs may improve the efficiency of traffic lights as drivers can start more quickly. Importantly, fossil fuel cars emit exhaust into the environment, while EVs do not. Global warming is

a concern for all humans, and EVs can help reduce the rate of greenhouse gas emissions. Electrical motors generate much less heat compared to engines, hence requiring lower cooling demands for vehicles. This can lead to revolutionary changes in appearance, as they no longer need to assimilate to the design constraints typically associated with traditional fuel vehicles.

3. Extreme weather

The other concern of EVs is the performance in extreme weather stability. Temperature can cause a significant effect on battery. Temperature can affect the maximum battery capacity.

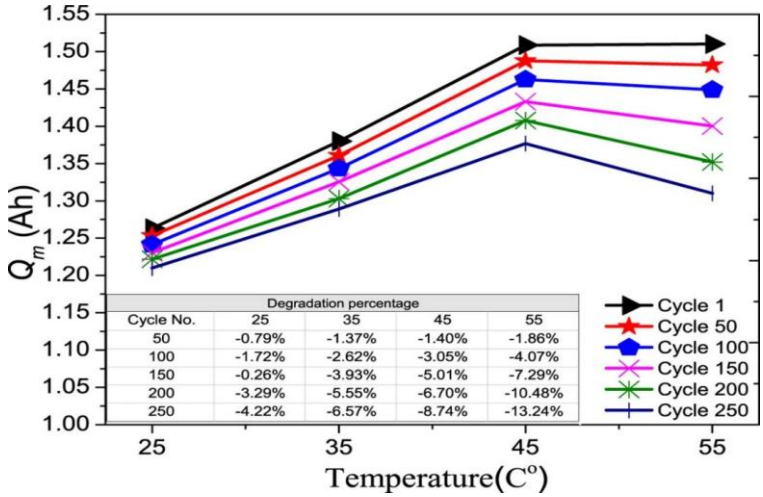

Fig 7. Capacity of a battery at different temperatures [7].

It can be seen from Fig. 7 that the battery has lowest charge capacity in 25ºC, which means when EV is working in a low temperature, range will further shorter than working in an ideal temperature. EVs may not be able to withstand extreme weather conditions because the battery requires a specific operating temperature.

4. Characteristic

4.1. Economic

The cost of driving an EV is around HK$0.26/km, but the fossil fuel cars is HK$1.97/km. EV can help driver save more money for the fuel. And the maintenance cost is lower, electric motor no need to maintenance so EV driver can save a large amount of money. As the engine of fossil fuel car is mechanical structure, wear and tear is inevitable and may require replacement, it may cost around HK$1k-10k.

4.2. Technology

EVs are highly compatible with high technology because most components in EVs are electrical, making it easy to integrate with software and provide a completely different experience for the driver and passengers. For example, the autopilot feature can reduce driving pressure on the driver.
Over-the-air updates (OTA) is a technology in EVs that allows them to be updated similar to how a phone receives operating system updates. This ensures that the software in EVs remains up to date until the hardware becomes incompatible.

5. Summary

Electric vehicles (EV) are more environmentally friendly than fossil fuel cars in terms of operational principles, as EVs do not emit any greenhouse gases, unlike fossil fuel cars. EVs can meet daily commuting needs in urban areas and offer a higher cost-effectiveness compared to fossil fuel

cars. Both in terms of operating costs and driving experience, EVs have lower driving costs relative to fossil fuel cars, with less driving pressure. The incorporation of high technology makes driving EVs more convenient and enjoyable.

EVs may experience unstable range in extreme weather conditions, but the future of automotive development is moving towards electrification to address range issues in extreme weather. This trend may lead to the phasing out of fossil fuel cars.

References

[1] Sanguesa JA, Torres-Sanz V, Garrido P, Martinez FJ, Marquez-Barja JM. A Review on Electric Vehicles: Technologies and Challenges. Smart Cities. 2021; 4(1):372-404.

[2] Campello-Vicente, Hector, et al. "The effect of electric vehicles on urban noise maps." Applied Acoustics 116 (2017): 59-64.

[3] Alturki, W. "Four-stroke and two-stroke marine engines comparison and application." International Journal of Engineering Research and Applications 7.4 Part 3 (2017): 49-56.

[4] Li, Sen. "A review of electric motor drives for applications in electric and hybrid vehicles." Researchgate, March (2017).

[5] Hashemnia, Nasser, and Behzad Asaei. "Comparative study of using different electric motors in the electric vehicles." 2008 18th international conference on electrical machines. IEEE, 2008.

[6] Rind, Saqib Jamshed, et al. "Configurations and control of traction motors for electric vehicles: A review." Chinese Journal of Electrical Engineering 3.3 (2017): 1-17.

[7] Leng, F., Tan, C. & Pecht, M. Effect of Temperature on the Aging rate of Li Ion Battery Operating above Room Temperature. Sci Rep 5, 12967 (2015).