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New-Energy Vehicle Transmission System Optimization and Design

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Abstract: This paper discusses the optimization and design of the new-energy vehicle transmission systems. Traditional automatic transmission systems suffer from fuel consumption and emissions issues, as well as limitations in the efficiency of mechanical transmission systems. In order to solve these problems, different types of transmission systems are used in new-energy vehicles, including battery electric vehicles (BEV), hybrid electric vehicles (HEV), and fuel cell electric vehicles (FCEV). The key factors for optimizing the transmission systems of new-energy vehicles include battery technology and energy management system, electric motor and electronic control system, energy recovery and reuse technology, and lightweight and aerodynamic design of the vehicle. This paper also introduces methods and tools for designing new-energy vehicle transmission systems, including simulation tools, optimization algorithms and data analysis, as well as experimental verification and testing methods. Besides, new-energy vehicle transmission system designs are proposed, and future challenges and development directions are discussed through case studies.

Keywords: New-energy vehicle; Transmission system; Optimization; Design; Strategy research

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1. Introduction

With the increasing global concern for environmental protection and sustainable development, the demand for new-energy vehicles is also increasing. The optimization and design of new-energy vehicle transmission systems has become a popular research topic. There are fuel consumption and emission problems in traditional automatic transmission systems, as well as limitations in the efficiency of mechanical transmission systems. These problems need to be solved through new technologies and design methods. New-energy vehicles adopt different types of transmission systems, such as battery electric vehicles (BEV), hybrid electric vehicles (HEV), and fuel cell electric vehicles (FCEV), to reduce dependence on fossil fuels and reduce emissions. The key factors for optimizing the transmission system of new-energy vehicles include battery technology and energy management system, electric motor and electronic control system, energy recovery and reuse technology, and lightweight and aerodynamic design of the vehicle. This paper aims to discuss the optimization and design of new-energy vehicle transmission systems, and successful designs are presented through case studies. At the same time, this paper will also discuss future challenges and development directions to promote further improvements and innovations in new-energy vehicle transmission systems.

2. The importance of new-energy vehicle transmission system optimization

The transmission system of traditional fuel vehicles has some limitations in terms of energy loss and efficiency, resulting in increased fuel consumption and emissions. By optimizing the transmission system, the efficiency of energy utilization can be improved and energy loss can be reduced, thereby reducing fuel consumption and emissions [1]. Second, traditional fuel vehicles are one of the main sources of greenhouse gas emissions, which have a negative impact on climate change and air quality. Optimizing energy vehicle transmission systems can reduce dependence on fossil fuels, lower greenhouse gas emissions, and improve environmental quality. The fourth-generation optimized transmission system provides smoother and more efficient power output, which enhance the driving experience [2]. The electric transmission system of new-energy vehicles has high torque and quick response, making acceleration faster and driving more comfortable. The optimization of the transmission systems of the fifth-generation new-energy vehicles can reduce operating costs. The transmission system of an electric vehicle is relatively simple, reducing the need for maintenance and upkeep. In addition, through energy recovery and reuse technology, the battery life can be extended, which reduces costs of replacement and repair. The optimization of the sixth-generation new-energy vehicle transmission system requires technological innovations in multiple fields, such as battery technology, motor control, energy management, etc. This has promoted the development of related industries and promoted the progress and innovation of new-energy vehicle technology [3].

3. Limitations of traditional automatic transmission system

3.1. Fuel consumption and emission issues

There are some limitations in terms of fuel consumption and emissions in the traditional vehicle transmission system, these problems need to be solved through the optimization of the new-energy vehicle transmission system. In response to these limitations, different types of transmission systems have been designed for new-energy vehicles, such as BEV, HEV, and FCEV, to reduce dependence on fossil fuels and reduce fuel consumption and emissions. The optimization of these new-energy vehicle transmission systems can effectively solve the problems of traditional vehicle transmission systems in terms of fuel consumption and emissions. The limitations of conventional automatic transmission systems in terms of fuel consumption and emissions are described below [4].

3.1.1. Fuel consumption

Traditional cars are powered by the combustion of fossil fuel by an internal combustion engine. However, the thermal efficiency of an internal combustion engine is limited, most of the energy generated by the fuel is lost in the form of heat, and only some can be converted into effective power output. This leads to a relatively high fuel consumption of conventional cars.

3.1.2. Carbon emissions

Emissions of greenhouse gases such as carbon dioxide (CO2) produced when internal combustion engines burn fossil fuels. These greenhouse gases are one of the main causes of climate change [5]. The large-scale use of traditional cars has resulted in a large amount of carbon emissions, which has a negative impact on climate change.

3.1.3. Pollutant emissions

In addition to carbon dioxide, the internal combustion engine of a traditional car also emits a series of pollutants, such as carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter (PM). These pollutants are harmful to air quality and human health, especially in the case of urban traffic congestion [6].

3.1.4. Energy dependency

The transmission system of a conventional car relies on non-renewable energy such as fossil fuel. With the depletion of global oil reserves and the issue of energy security, the energy dependence of conventional vehicles becomes a major challenge.

3.2. Efficiency limitation of mechanical transmission system

Mechanical transmission systems in conventional automatic transmission systems have limited energy efficiency, which will affect their drivability. In order to increase the efficiency of mechanical transmission systems, new-energy vehicles adopt electric transmission systems, in which the electric motor directly drives the wheels, avoiding the transmission losses in and increasing the efficiency of multi-speed transmissions [7]. The electric transmission system has high efficiency, high responsiveness, and a more simplified structure, resulting in better energy efficiency and drivability. The following are limitations of mechanical transmission systems in terms of efficiency.

3.2.1. Transmission loss

Various transmission elements (such as gears, bearings, transmission belts, etc.) in the mechanical transmission system will generate friction and mechanical loss when transmitting power. These transmission losses result in wasted energy and reduced efficiency. Especially under long-term running and high-load conditions, the transmission loss will be more significant.

3.2.2. Efficiency loss of multi-speed transmission

Conventional cars are usually equipped with multi-speed transmissions to provide suitable torque and power output in different speed ranges. However, the switching and gear matching process of the multi-speed transmission will cause energy loss and decrease in efficiency. In addition, the weight and complexity of the multi-speed transmission will also affect the efficiency of the entire transmission system [8].

3.2.3. Limitations of power transmission path

The mechanical transmission system of a traditional car transmits power from the engine to the wheels through the drive shaft. However, the length and angle of the transmission shaft have a certain effect on the transmission efficiency. Long drive shafts increase transmission losses, while steeply angled drive shafts cause vibration and energy loss.

3.2.4. Responsiveness of power output

The responsiveness of mechanical transmission systems are affected by the inertia of the transmission components and the delay of the transmission process. This can lead to lag and instability in power delivery, affecting the driving experience and vehicle performance.

4. Types of new-energy vehicle transmission systems

4.1. BEV transmission systems

In BEVs, the battery pack is the only energy storage device, and the electric motor directly drives the wheels to generate power. The battery pack is responsible for storing and releasing electrical energy, and the electric motor converts electric energy into mechanical energy to drive the vehicle. The BEV transmission system does not require traditional engines and fuel systems, and has a simplified structure and high energy efficiency. Charging is a key link in the BEV transmission system, and proper charging infrastructure needs to be established to support long-distance travel and daily use [9].

4.2. HEV transmission system

HEVs are powered by a combination of an internal combustion engine and an electric motor (**Figure 1**).

The internal combustion engine can drive the wheels directly and charge the electric motor via a generator simultaneously. The electric motor can provide additional power, and the braking energy is converted into electrical energy and stored and through an energy recovery system. HEV transmission systems have high energy efficiency and long cruising range and are less dependent on charging infrastructure [10].

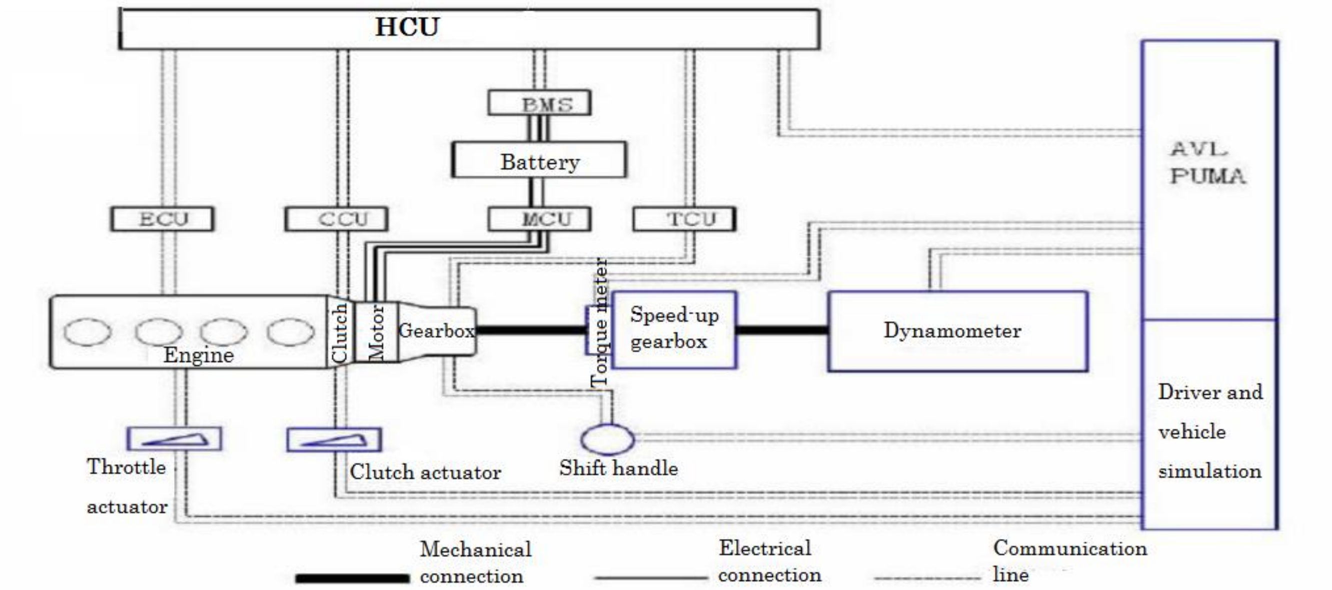

Figure 1. HEV transmission system

4.3. FCEV transmission system

FCEV use hydrogen as fuel, and the hydrogen reacts with oxygen through fuel cells to generate electricity that powers the electric motor. The emission of fuel cell vehicles is only water vapor, which achieves zero emission. FCEVs has the advantages of fast hydrogen refueling and long cruising range, but there are still some challenges in the construction of hydrogen infrastructure.

5. Key measures to optimize the transmission system of new-energy vehicles

The key measures to optimize the transmission systems of new-energy vehicles are described in **Figure 2**.

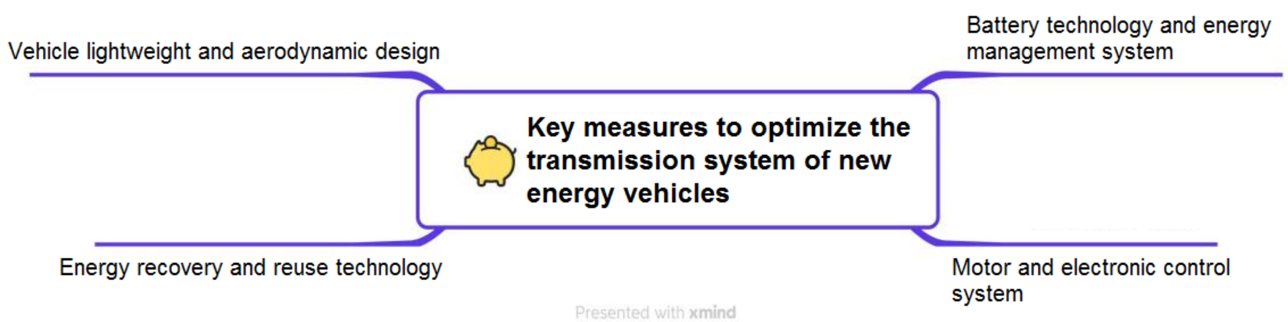

Figure 2. Key measures to optimize the transmission system of new-energy vehicles

5.1. Battery technology and energy management system

One of the key measures to optimize the transmission systems of new-energy vehicles is to improve battery technology and the energy management system. These measures can improve the performance and life of the battery while maximizing the utilization of energy of the battery. In terms of battery technology, researchers can work on developing batteries with higher energy density and higher power output. Batteries with high energy density can provide longer cruising range, while batteries with high power output can provide better acceleration performance [11]. In addition, it is also important to improve the cycle life and charging speed of batteries.

Optimization of energy management systems can be achieved through several ways. First, the development of intelligent energy management algorithms control the charging and discharging process of the battery more effectively to maximize the battery life. Second, adopting advanced energy recovery technologies, such as braking energy recovery and kinetic energy recovery systems can convert the energy generated while the vehicle is driven into electrical energy and store it in the battery. In addition, optimizing the vehicle's overall energy system including electric motors and electronic control units can improve energy efficiency. In addition to technical improvements, the government and related agencies can also take measures to promote the development of new-energy vehicles. For example, providing financial support and tax incentives to encourage the R&D and production of key technologies for new-energy vehicles. In addition, establishing a charging infrastructure network that is more complete is also an important measure to promote new-energy vehicles.

5.2. Motor and electric control system

Another key measure to optimize the transmission system of new-energy vehicles is to improve the motor and electronic control system. These measures can improve the efficiency and performance of the motor [12]. Researchers can work on improving the power density and efficiency of electric motors. Increasing the power density can enable the electric motor to provide greater output power under the same volume or weight, thereby improving the acceleration performance of the vehicle. Improving efficiency can reduce the energy loss of the electric motor and improve the energy efficiency of the transmission system.

In addition, it is also important to the thermal management system of the motor because a lot of heat is generated during the operation of the motor. If the heat generated cannot be dissipated properly, the motor will overheat, and its performance and lifespan will be affected. Therefore, the heat dissipation system should be optimized with efficient cooling techniques and materials, which will improve the reliability and durability of the electric motor.

In terms of electronic control systems, researchers can work on developing more advanced electronic control algorithms and strategies. These algorithms and strategies can achieve precise control of the motor even under different driving conditions [13]. For example, the output power and torque of the electric motor are dynamically adjusted according to factors such as vehicle speed, load and driving mode, so as to provide the best driving experience and energy efficiency. In addition, improving the reliability and safety of electronic control systems is also an important goal. The electronic control system of electric vehicles needs to be able to detect and respond to faults in time to ensure the safety and reliability of the vehicle. Therefore, it is necessary to adopt advanced fault diagnosis technology and safety protection measures.

5.3. Energy recovery and reuse technology

Another key measure to optimize the transmission systems of new-energy vehicles is to adopt energy recovery and reuse technology, in which the energy generated during the driving of the vehicle is recovered and reused to improve energy efficiency. A common energy recovery technology is braking energy recovery system, also known as regenerative braking system. When the vehicle brakes, the energy generated by braking is lost as heat energy. With regenerative braking, braking energy is converted into electricity and stored in the battery for later use. This can reduce energy waste and increase the cruising range of the vehicle [14]. In addition to braking energy recovery, there are other energy recovery technologies that can be applied to new- energy vehicles. For example, a kinetic energy recovery system can convert the inertial energy generated when a vehicle is moving into electrical energy and store it. With this technology, energy can be generated when the vehicle is decelerating or moving, further improving energy efficiency. In addition, solar charging technology can also be used in new-energy vehicles . By installing solar panels on the vehicle, solar energy can be converted into electricity that can be used to recharge or power the vehicle’s auxiliary systems. This technology reduces dependence on the grid and increases the vehicle’s self-sufficiency. In addition to energy recovery technology, energy reuse is also one of the key measures to optimize the transmission systems of new-energy vehicles. For example, using the energy stored in the battery to power or drive the vehicle's auxiliary systems can reduce the load on the engine and improve the efficiency of the entire transmission system.

5.4. Lightweight and aerodynamic design of the vehicle

Another key measure to optimize the transmission systems of new-energy vehicles is the lightweight and aerodynamic design. A lightweight and aerodynamic design reduces the vehicle’s weight and air resistance, thereby improving energy efficiency and driving performance. The vehicle’s weight can be reduced through the use of lightweight materials and an optimized design. Common lightweight materials include high-strength steel, aluminum alloy, carbon fiber composite materials, etc. These materials have high strength and rigidity, which can reduce weight while ensuring the safety of vehicle structure. In addition, the weight of the vehicle can also be reduced by optimizing the vehicle’s structural design and component layout, such as reducing unnecessary parts and using a compact structure.

An aerodynamic design reduces air resistance by optimizing the shape and hydrodynamic characteristics of the vehicle. Reducing air resistance can reduce the energy required to drive the vehicle, thereby improving cruising range and driving efficiency. The air resistance of the vehicle can be reduced by improving body lines, reducing protruding parts, and optimizing the design of the vehicle floor. In addition, other measures can be adopted to further reduce the weight of the vehicle while having an aerodynamic design [15]. For example, advanced manufacturing processes and technologies such as 3D printing and simulation optimization can be used to increase the accuracy and efficiency of component manufacturing and design. Additionally, the vehicle’s aerodynamic performance can be evaluated and improved using advanced computational fluid dynamics (CFD) simulations and wind tunnel testing.

6. Conclusion

There are several key measures that can be taken in optimizing and designing energy vehicle transmission systems, such as improving battery technology and energy management systems, optimizing electric motors and electronic control systems, adopting energy recovery and reuse technologies, and lightweight and aerodynamics design. These measures are taken to increase energy efficiency and cruising range, improve drivability, and reduce environmental impact. Through these optimization and design measures, we can produce transmission systems that are more efficient and greener. This not only helps to reduce dependence on traditional petroleum energy and reduce greenhouse gas emissions, but also improves driving experience and reduces operating costs. Besides, these measures can also promote the development and innovation of new-energy vehicle technology and the realization of sustainable transportation. However, the joint efforts of all parties such as the government, research institutions, automakers, and consumers are needed to realize the optimization and design of transmission systems. Only through continuous innovation, technological advancement, and policy support can we achieve a more sustainable and environmentally friendly transportation future. In the future, we can look forward to the continuous development and improvement of energy vehicle transmission systems to meet people’s needs for more efficient and environmentally friendly modes of transportation. Through continuous research, we can develop transmission systems that are more intelligent, efficient, and sustainable, which will benefit our society and environment.

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Disclosure statement

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