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Structural Strategy Analysis of Transmission System for New Energy Vehicles

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Abstract. In recent years, the market share of new energy vehicles has increased year by year, and the relevant infrastructure has also been rapidly popularized. People's desire to buy trams is also gradually rising. So this puts forward higher requirements for the quality of new energy vehicles. The transmission system is an important part of the power system in both traditional fuel vehicles and new energy vehicles. This paper takes the transmission system and its structure of new energy vehicles as the research object, classifies and compares them horizontally according to the number of motors and hybrid type systems, and analyzes the advantages, disadvantages and performance differences of different transmission forms and structures. Finally, this paper puts forward the possible development direction of the transmission system in the future. This article roughly compares the advantages and disadvantages of various transmission forms, and provides some references and suggestions on how to choose different transmission forms for different new energy vehicles.

Keywords: New energy vehicle, powertrain, transmission structure, drive system

1. Introduction

With the development and progress of society, the public's interest in traditional diesel locomotives has gradually declined, and the market sales are also declining year by year. New energy vehicles have replaced their position, and have been widely recognized by all sectors of society. In 2024, the global sales of electric vehicles (passenger cars) exceeded 17million for the first time, with a year-on-year increase of 26%. Among them, the sales of plug-in hybrid vehicles increased by 53% year-on-year, and the sales of pure electric vehicles increased by 14% year-on-year.It can be seen that, driven by the Chinese market, the growth rate of plug-in hybrid vehicles is higher, and the proportion of plug-in hybrid vehicles in global electric vehicle sales will reach 37% in 2024.At the same time, the proportion of electric vehicle sales in global vehicle sales is also rising steadily, especially in December 2024, the market share of electric vehicles jumped to 30%, setting a new record [1]. From the cumulative data, from January to June 2025, the cumulative production and sales of new energy vehicles will be 6.968 million and 6.937 million, respectively, with a cumulative year-on-year increase of 41.4% and 40.3% respectively, and the cumulative market share will reach 44.3% [2]. The development of energy-saving and new energy vehicles poses new challenges to

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vehicle transmission technology. In order to reduce vehicle fuel consumption and adapt to different energy-saving and new energy vehicle products, vehicle transmission technology must carry out new innovations and take a new technical route [3].

Different vehicles will have different transmission systems due to different types of power units, frame structures, and use scenarios. This paper aims to study the advantages and disadvantages of different models and different types of transmission forms, as well as the use scenarios, innovations, and challenges. The transmission system has complexity and unity, and the research in related fields of vehicle engineering will make a very important contribution to the upgrade of the power system of new energy vehicles. SongWenxi proposed the optimal design scheme of the main transmission shaft and the secondary transmission shaft for the defects of the automobile transmission system [4]. WangYangguang took the planetary row hybrid power system as the research object, and proposed a configuration design and optimization method of Hybrid Electric Vehicle Powertrain based on the lever method [5]. These studies have put forward very good and constructive suggestions for the optimization of the transmission system of new energy vehicles.

The research on the complexity of hybrid power, the efficiency of electric drive, the integration of diversified energy and collaborative control strategy will provide theoretical support for the progress of new energy vehicle technology [6].

This paper takes the power transmission system and structure of new energy vehicles as the research object, classifies and compares them horizontally according to the number of motors, analyzes the similarities and differences, advantages and disadvantages of different structures, compares the performance differences, and provides possible effective solutions for the deficiencies. This study analyzes how different manufacturers and users should choose the structure of the power transmission system according to different needs of the market, and looks forward to the future development prospect of the new energy vehicle transmission system structure, so as to effectively promote the development of new energy vehicle technology and market.

2. Transmission system of new energy vehicles

2.1. Single motor drive transmission system

At present, the single motor vehicle is relatively simple in structure and control system. Because its layout is similar to that of a conventional energy-powered vehicle. However, the transmission form of a single motor drive varies greatly according to different vehicle types. It is composed of a motor and the controller of the power supply, transmission, and motor. Because it has too many similarities with the structure of internal combustion engine vehicles, the structure is relatively stable, and it is also convenient to produce on the original production line [7].

2.1.1. Hybrid electric vehicle

The traditional fuel engine is still the main power source of the hybrid electric vehicle, and the electric motor only plays a certain role in power assistance. The combination of the two forms the power system of the vehicle. According to different motor positions, the layout of the transmission system is also different. The first is the P0 type structure, that is, the BSG structure. The motor is arranged at the engine inverter position of the traditional fuel vehicle, and there is a flexible connection with the belt. At present, Mercedes-Benz hybrid vehicles adopt this layout. The next is the P1 type structure (ISG). The motor is arranged behind the engine and connected to the engine crankshaft before the clutch. This motor replaces the position of the original starting motor and uses

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the rotor of the motor instead of the flywheel of the traditional engine. The current Honda Civic hybrid and the first-generation Honda IMA hybrid, the Insight, both use the P1 layout. The P2 type layout motor is arranged behind the clutch and in front of the transmission, and is connected to the transmission input shaft. At present, most European car companies choose P2 layout to develop a 48V weak hybrid system. The other is the P3 layout. The motor is arranged behind the transmission and connected to the transmission output shaft. It has two forms, one is the coupling of the motor and the output shaft of the gearbox, and the other is directly integrated in the gearbox. At present, for example, BYD Qin, Volkswagen Suteng and Volvo T5 front drive hybrid use this type of transmission.Finally, P4 layout. The motor is arranged on the rear axle. The engine is still the main power source, and the motor only plays a role of power assistance. Table 1 shows the configuration and structural characteristics in the form of tables.

Table 1. Basic type classification of hybrid power systems

Basic configuration	Structural features
P0(BSG)	The motor is located in the position of the conventional starter of the engine
P1(ISG)	The motor is connected to the engine crankshaft
P2	The motor is connected to the input shaft of the transmission
P3	The motor is connected to the output shaft of the transmission
P4	The motor is located in the rear axle and the transmission is directly/indirectly connected to the wheels
DHT	Multiple power sources constitute a hybrid transmission

2.1.2. Plug-in hybrid electric vehicle

Compared with the transmission fuel vehicle, the plug-in hybrid electric vehicle is equivalent to the conversion of the proportion of electricity and traditional energy supply. This hybrid structure is equivalent to adding a motor and generator to the traditional mechanical structure of the fuel vehicle, and replacing a larger power battery. This type of new energy vehicle is equipped with two drive systems, and there is also a mechanical connection between the two systems. This means that this model can be driven by fuel, an electric motor, or by both. The shaft drive is still the main type of transmission. The differential axle is used to transmit power to the wheels. At present, many manufacturers such as Toyota, Geely, and Ford are developing plug-in hybrid vehicles.

2.1.3. Extended range electric vehicle

This model is driven by an electric motor, and the engine is only a generator to charge the battery. This type of transmission system is a series hybrid system. It is equivalent to adding a power generation system based on the engine to the traditional single-motor electric vehicle. When the battery power is lower than a certain threshold, or the power requirement is high, and the power consumption is too fast, the engine will start to supply power to the motor battery. This model still uses the differential axle shaft to transmit power, but there is also a power separation device to start or stop the power supply at any time. At present, many emerging new energy forces are using the incremental program as their main trolley drive mode. For example, Zhiji ls6, Wenjie M7, ideal L6 and other models all use the extended program as the driving mode. Zongfaxin et al. Matched the parameters of the key components of the extended range vehicle powertrain, used the multi-point

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control strategy, and simulated it in advisor software to verify the rationality of parameter matching and control strategy [8]. Weng Yongyong takes the extended range electric vehicle as the research object, studies the impact of energy management strategy on vehicle economy and battery life, proposes a multi-point control strategy in different regions, and uses Ni-pxi system to establish a hardware in the loop simulation test platform to verify the effectiveness of the control strategy [9]. At present, for the development of extended range vehicles, there are many researches on the power system and electronic control system. Ye Yang presents a novel fuzzy adaptive PI coordination control strategy for the Auxiliary Power Unit (APU) in range-extended electric vehicles (EREVs) to enhance dynamic and steady-state performance during power tracking. An improved genetic algorithm is utilized to optimize the PI controller's parameters, focusing on faster convergence. A fuzzy reasoning algorithm is then employed to dynamically adjust the APU's control parameters, achieving adaptive control during power tracking. Experimental verification is conducted through bench tests, where dynamic response characteristics and power change rates of the APU are evaluated. Comparative simulations with traditional control methods demonstrate that the proposed strategy significantly improves the APU's dynamic response, offering better real-time adaptability and steady-state accuracy, effectively addressing challenges posed by power variations [10].

2.1.4. Pure electric vehicle

The layout of pure electric vehicles driven by a single motor is very similar to that of traditional fuel vehicles. Only the motor replaces the position of the original engine to provide power for the wheels. A single motor is supplemented by a power supply, and the motor and battery controller function the same as the engine. Therefore, there are also pure electric front drive and pure electric rear drive, which are driven by a differential axle shaft. Because the power of single motor is limited, it is difficult to realize a single motor four-wheel drive. At present, many pure electric vehicles with low cost and price generally use a single motor to drive. In order to ensure the controllability and space considerations of most tram models in the market, most manufacturers put the motor behind to realize rear drive. At present, many new energy vehicle manufacturers are producing a large number of pure electric vehicles, which is also the largest number of new energy vehicles in the market.

2.2. Dual motor drive transmission system

2.2.1. Hybrid electric vehicle

The structure of the hybrid electric vehicle is similar to that of the parallel hybrid electric vehicle, and there are two kinds of drive systems, but there are two motors in the hybrid electric vehicle. The transmission systems of these two motors are different according to different use scenarios. The first is that one motor is responsible for driving the car, and the other motor is responsible for energy recovery to charge the battery, which is similar to the role of the engine. At this time, the single motor still transmits power to the wheels, which is the axle drive differential axle drive. In the second type, two motors are respectively located on the front and rear axles of the vehicle to achieve the four-wheel drive effect. The electronic control system, two differentials and fixed gear ratio gearbox are used for differential speed. The third kind is relatively rare. Two motors are respectively distributed on the wheel side, and two hub motors and planetary reducers are used to supply power to the two wheels respectively.

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There are also relevant cutting-edge research results on hybrid electric vehicles. Three kind of structure of HEV and their control strategy were investigated: Series Hybrid Electric Vehicle, Parallel Hybrid Electric Vehicle, and PSHEV. Considering about driving cycle of CYCEDC and CYCWFET, three control strategies such as Electric Assistant Control, Adaptive Control Strategy and Genetic Algorithms Control were simulated based on Advisor to analysis vehicle performance. The results of the simulation indicated that the fuel consumption economics and exhaust characteristics were improved by using Genetic Algorithms Control [11].

2.2.2. Pure electric vehicle

If pure electric vehicles are driven by dual motors, basically all models on the market are dual-motor four-wheel drive. The fixed gear ratio reducer is used to connect the motor with the axle; that is, the differential, reducer, motor and axle shaft assembly are on the front and rear axles. In this way, the differential control between four-wheel drive and wheels is realized through the structure of the electronic control system and mechanical device. At present, the dual motor pure electric vehicles on the market generally adopt the four-wheel drive layout.

2.3. Three motor drive system

Three motor drive means that the whole vehicle is equipped with three motors. At present, most pure electric vehicles on the market are single motor with front axle, fixed gear ratio gearbox, and a reducer differential integrated on the front axle. The half axle transmits power to the wheels on both sides, responsible for low-speed cruising and the starting stage. The other two motors drive the left rear wheel and the right rear wheel, respectively, providing better power output and handling stability. A motor drive system usually adopts a wheel-side reducer to provide power for the wheels. At present, many brands in the market, such as large and medium-sized SUVs and sedan models with main power control, will adopt this three-motor layout.

2.4. Four motor drive system

Four motor drives are to arrange a wheel motor on each of the four wheels of the vehicle, and the motor transmits power to the wheels after decelerating with the wheel reducer of the integrated planetary reducer. Because of the cost and weight, only a few luxury SUVs use this drive mode.

3. Analysis of transmission system assembly of different single motor vehicles

3.1. Hybrid electric vehicle

3.1.1. Analysis of advantages and disadvantages of P0 system

P0 system structure is a motor instead of an inverter, so that when the engine stops for a short time, the vehicle can drive the electrical system to run normally without relying on the continuous operation of the engine to obtain power, so as to save fuel and improve endurance.However, there are some problems that can not be ignored in this layout. The belt connection makes it unable to run at high power; that is, it cannot provide power for the engine or recover kinetic energy, and only plays an automatic start and stop function. Therefore, this also determines that its energy-saving effect is not strong, and the improvement effect of endurance is not obvious.

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3.1.2. Analysis of advantages and disadvantages of P1 system

Compared with the P0 system, the P1 system layout not only has the advantages of P0, but also has the advantage that its motor is directly connected to the crankshaft, and its transmission efficiency is much higher. However, it also has corresponding disadvantages. Its speed must be equal to the crankshaft speed of the engine. Therefore, the power and torque of the motor must be large enough, which inevitably leads to the corresponding increase in the volume of the motor, which leads to the corresponding increase in the volume of the engine. It also needs to occupy more space in the passenger compartment, and the cost of redesign will also increase. Secondly, the rotation of the motor will drive the engine crankshaft to rotate, so when the kinetic energy is recovered, the crankshaft will waste excess kinetic energy due to idling, and the noise and wear of the engine will correspondingly increase.

3.1.3. P2 system advantages and disadvantages analysis

P2 layout, the motor is arranged behind the engine clutch and in front of the gearbox, so the layout forms are more flexible and diverse. It can be directly connected to the output shaft, or connected to the input shaft of the gearbox through a belt, tooth drive and other forms. The power source can also be changed by switching the clutch. The advantage of this structure is that the motor can not only directly provide power for the wheels, but also cut off the connection with the engine during kinetic energy recovery. At the same time, the variable transmission ratio further reduces the carrying load of the motor. But it also has the problem of power discontinuity, because when switching power, there is a problem of connection sequence between the mechanisms, which leads to its high requirements for the gearbox, and it can not adapt to the manual gear.At low and medium speeds, the engine is also required to participate, so its efficiency and NVH cannot reach a particularly ideal level.

3.1.4. Analysis of advantages and disadvantages of P3 system

The compact structure of P3 leads to a more flexible layout and space of the transmission system, which is more suitable for rear drive. Moreover, the P3 system structure can be perfectly adapted to hybrid vehicles in new energy vehicles. Because it can perform an output shaft power switching operation with the double clutch gearbox. In P3 structure, the motor can be integrated on one of the shafts of the gearbox, so that the motor can not only provide power to the wheels independently, but also carry out independent kinetic energy recovery without connecting the engine, and can drive more efficiently, and can also switch gears for power output. These advantages can make up for the problems of double clutch and traditional energy vehicles' faltering start and high fuel consumption when the vehicle is in low-speed urban traffic congestion and starting. However, due to the complex structure and high integration, the maintenance will be more difficult, and the motor in the gearbox cannot directly start the engine, which requires additional starting motor and battery system with larger capacity.In addition, in order to meet the function of automatic start and stop, the power and life requirements of the starting motor will be higher, further increasing the cost and weight.

3.1.5. Analysis of advantages and disadvantages of P4 system

The biggest feature of the P4 system structure is that the power take-off shaft of the engine and the shaft where the motor is located are not the same shaft. In this way, some similar drive forms of traditional fuel vehicles can be realized, such as 4WD. Take the BMW I8 as an example. During

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pure electric driving, only the click placed on the front axle of the car body is used for power output, and the engine does not provide any power. During hybrid driving, the main power source is switched to the engine at the rear of the car body, and the motor only plays an auxiliary role, realizing the four-wheel drive system with unequal power between the front and rear wheels. The motor can be charged when the engine is started. But there are also some problems. The driving mode cannot be switched at will when driving, because this parallel power output form cannot be switched directly in structure. At the same time, it is inevitable that the power output falters when switching, which has a negative impact on driving comfort and handling.

3.2. Analysis of advantages and disadvantages of PHEV transmission

The biggest difference between PHEV and HEV is the change of the proportion of power sources. Plug in hybrid electric vehicle is mainly driven by a motor, and the engine becomes the auxiliary power unit. Generally speaking, it is to add a large charging device to the traditional hybrid vehicle. It can be driven by a motor to achieve the same zero-emission and quiet driving as pure electric vehicles, and it can also start the engine to provide additional power for endurance. This model is usually equipped with two sets of drive systems, similar to the P4 layout in HEV, but the structure of each power source is complete, rather than integrated. In this way, it can output in three modes and charge when the engine is driven, which greatly improves the range and alleviates the problem of charging limitation. However, there are many similar structural redundancies in such a structure. The transmission shaft and output shaft and the structure are repeated. At the same time, the existing motor, battery, engine and its transmission system will lead to excessive weight, increased fuel and power consumption, and narrower interior space. Therefore, the problem of excessive energy consumption cannot be effectively solved. Moreover, this type of vehicle is generally driven before or after, and the transmission system structure is also more complex.

3.3. Analysis of advantages and disadvantages of extended range electric vehicle transmission

The biggest difference between the extended range vehicle and the new energy vehicle described above is that the engine is no longer used as a power source, but a generator to charge the battery. The generator is composed of a relatively small engine and a power separation device. The function of the power separation device in his transmission mechanism is to connect the engine with the generator on the battery when the vehicle detects that the battery power of the vehicle is lower than a certain value and the user is still driving without charging, and charge the battery through the engine-driven generator. Once the power is above a certain threshold or the user starts charging, the separation device will automatically cut off the power link between the engine and the generator. Because the vehicle is driven by the motor and uses the traditional transmission form, it can solve the frustration feeling, at the same time, the torque is larger, the power output is more continuous, and the noise is relatively small. This layout also solves the problem of users' endurance mileage. The lighter transmission mechanism also makes the wear smaller, the weight lighter and the service life longer. The transmission system of the extended range vehicle is highly integrated, thanks to the smaller engine and motor drive. But it also has corresponding shortcomings. When driving at a distance without charging, the engine will be used to burn fuel to obtain power, and then the motor will use the energy in the battery to drive the wheels. At this time, the driving efficiency will be greatly reduced, the loss will increase, the energy conversion efficiency will be lower, and the use cost will be greatly increased for some user scenarios.

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4. Analysis of transmission system assembly of multi motor vehicle

4.1. Hybrid electric vehicle

The hybrid electric vehicle is a new motor based on the single motor new energy vehicle. This motor does not participate in the driving of the vehicle at ordinary times, and only provides kinetic energy recovery to charge the battery during braking and taxiing. At this time, the function of the motor is similar to that of the engine in the extended range new energy vehicle. This motor is usually located on another axle besides the main motor. When power supply is required, it will supply wheel power through a fixed gear ratio reducer. There is also a planetary gear reducer with two motors distributed on the coaxial wheel side. This driving mode makes the driving mode more flexible, which can be switched freely according to different operating conditions, and the fuel economy and endurance ability are very competitive. However, because the structure is particularly complex, the technical requirements for the adjustment of the control system are also very high to ensure the normal operation of the vehicle. This has led to the high price of such models, and the high manufacturing costs and prices have led to the scarcity of models in the market.

4.2. Transmission system analysis of pure electric vehicle

In addition to the single motor new energy vehicles, the dual motor pure electric vehicles basically have two motors distributed on the front and rear axles of the vehicle, and the four-wheel drive is realized through the reducer with a fixed gear ratio. Compared with the traditional four-wheel drive system, the four-wheel drive system of the pure electric vehicle is simpler in mechanical structure, which can make the space in the vehicle larger, and at the same time, the energy consumption of the vehicle will be relatively reduced due to the reduction of self-weight. At the same time, because the control of the motor is controlled by the program of the electronic control system, the handling of the vehicle will be better. However, this type of power system cannot avoid the high requirements for electronic systems. The layout of three motor vehicles usually adopts the form of a single motor at the front axle and double motors at the rear axle, and four motors only have four wheel hub motors. The price of these two models will inevitably increase due to the increase in the number of motors. At the same time, due to the increase in energy consumption, it is inevitable to choose between performance and endurance. And the electronic control system will be more difficult. Because the transmission form is no longer based on mechanical structure, but through the controller to realize the power output control, so according to different road conditions, the differential adjustment between wheels is also very important. The planetary reducer is relatively small in size, which is very suitable for combining with the wheel motor to reduce the volume to the greatest extent. At the same time, the independent suspension can be used instead of the integral rear axle, so that the handling performance is better.

5. Conclusion

Against the background of the continuous development of new energy vehicle-related technologies and the more compact and reliable mechanical structure design, how to maximize the transmission efficiency while controlling the cost, the comfort of riding and driving, and the convenience of maintenance have become important issues for new energy vehicle enterprises to consider. This paper systematically examines the transmission system structure of existing new energy vehicles around this related problem, compares the performance of different transmission structures, and

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analyzes the advantages and disadvantages of various transmission systems. On this basis, it also points out and prospects the optimization direction and progress prospect of the transmission system of new energy vehicles in the future, which improves the overall performance of the transmission system.

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