Simulation Analysis of Performance Comparison between Distributed Drive and Centralized Drive Electric Vehicles

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Abstract: In order to improve the transmission efficiency as well as the range of centralized drive electric vehicle and simplify the structure of the whole vehicle, a distributed drive electric vehicle is adopted. Taking a single-motor centralized drive electric vehicle as a reference object, the original model was changed to a distributed drive model according to the structural of distributed power system electric vehicles. The Cruise software is used to establish two types of electric vehicle models, centralized and distributed, and to verify the correctness of the centralized model based on the experimental data of the actual driving of the original vehicle. Analyzing the simulation results of dynamic and economy of the two models, it can be concluded that all the indicators of distributed electric vehicles meet the target requirements, and the performance of distributed electric vehicles is better than that of centralized electric vehicles.

1. Introduction

With the rising standard of living, the number of private cars is increasing worldwide, and the resulting problems such as oil shortage, environmental pollution, and climate warming have become common challenges for the automotive industry worldwide [1]. Pure electric vehicles have been considered as an important new energy vehicle in line with the future development trend [2]. Therefore, electric vehicles have become the focus of research and development in the automotive industry of various countries, and electrification has become an inevitable trend in the development of automobiles [3]. Compared with the traditional single-motor centralized drive electric vehicles, the distributed power system electric vehicles based on wheelside or hub motors eliminate the complex transmission system such as transmission and differential, which has the advantages of high transmission efficiency, good vehicle stability, and saving chassis space.

2. Parameter Design of Power System

2.1 Motor Parameters Matching

2.1.1 Motor Power Determination

The drive motor is the only power source of the electric vehicle. The permanent magnet synchronous motor is selected, which has the advantages of small size, light weight, compact and simple structure, and high power density [4].

1)Based on the maximum vehicle speed.

$$P_{m1}=\frac{1}{\eta_T}\left(\frac{mgf_{\mathrm{r}}u_{\max}}{3600}+\frac{C_D A u_{\max}^3}{76140}\right) \quad (1)$$

2)Based on the maximum climbing degree

$$P_{m2}=\frac{1}{\eta_T}\left(\frac{mgf_{\mathrm{r}}\cos\alpha_{\mathrm{m}}u_{\mathrm{a}}}{3600}+\frac{mg\sin\alpha_{\mathrm{m}}u_{\mathrm{a}}}{3600}+\frac{C_D A u_a^3}{76140}\right) \quad (2)$$

3)Based on the acceleration time

$$P_{m3}=\frac{1}{3600t\eta_T}\left(\frac{mgf_{\mathrm{r}}u_f t}{1.5}+\frac{C_D A u_f^3 t}{52.875}+\frac{\delta m u_f^2}{7.2}\right) \quad (3)$$

The rated power of the drive motor shall enable the electric vehicle to reach the maximum speed, and the peak power shall not only meet the requirements of the maximum speed, but also meet the requirements of the maximum climbing degree and acceleration, so the power of the drive motor shall meet the following equation.

$$P_e \geq P_{m1}$$

$$P_{e\max} \geq \max\left\{P_{m1},\ P_{m2},\ P_{m3}\right\}$$

$$P_{e\max}=\lambda P_e \quad (4)$$

2.1.2 Motor Speed Determination

The peak speed of the motor and the maximum speed of the electric vehicle satisfy the following equation (5), and the relationship between the peak speed and the rated speed of the motor satisfies the following equation (6).

$$n_{e\max}=\frac{u_{\max} i_0}{0.377r} \quad (5)$$

$$n_e=\frac{n_{e\max}}{\beta} \quad (6)$$

2.1.3 Motor Torque Determination

The peak torque and rated torque of the motor satisfy the following equation.

$$T_{\max}=9550\frac{P_{e\max}}{n_0} \quad (7)$$

$$T_e=9550\frac{P_e}{n_0} \quad (8)$$

After the above calculation, the basic parameters of the hub motor are shown in Table 1.

Tab.1 Basic parameters of hub-motor

Parameters	Value
Rated speed/(r·min^{-1})	700
Peak speed/(r·min^{-1})	1400
Rated power/kW	12
Peak power/kW	24
Rated torque//(N·m)	175
Peak torque//(N·m)	350

2.2 Battery Parameter Matching

Ternary polymer lithium batteries have high specific power and specific energy, and have the advantages of long cycle life, which can be used as the preferred power source for electric vehicles. The total battery energy is determined by the maximum driving range. The total battery energy determined by the maximum driving range is calculated by the formula:

$$W_{ess} \geq \frac{1}{\eta_{ess}\eta_T}\left(\frac{mgf}{3600}+\frac{C_D A u_b^2}{76140}\right)\cdot S \quad (9)$$

The relationship between the total energy of the battery pack and the total capacity is as follows:

$$W_{ess} = \frac{U_{ess} \cdot C_{ess}}{1000} \quad (10)$$

After the above calculation, the basic parameters of the battery are shown in Table 2.

Tab.2 Basic parameters of battery

Parameters	Value
Battery type	Ternary polymer lithium battery
Number of individual batteries/pc	264
Total battery energy (kWh)	49.14
Battery unit voltage (V)	3.65
Total battery capacity (Ah)	153
Total battery voltage (V)	320

3. Comparison of Drive System Structures

The structure of single-motor centralized drive system is shown in Figure 1. The drive system consists of motor, transmission, differential, and wheels.

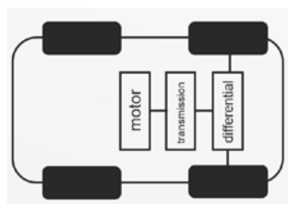


Fig.1 Single-Motor Centralized Drive Electric Vehicle Drive System Structure Diagram

The distributed drive electric vehicle is modified by installing the motor directly in the wheel, eliminating the mechanical transmission devices such as the main reducer and differential, and replacing the main reducer and differential by the motor controller. The structure of the distributed drive electric vehicle is shown in Figure 2.

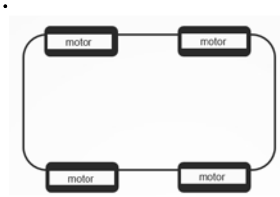


Fig.2 Distributed Drive Electric Vehicle Drive System Structure Diagram

Distributed-drive electric vehicles have the advantages of high transmission efficiency, simple overall vehicle structure, and can recover energy when the vehicle brakes and decelerates to improve the economy of the whole vehicle.

4. Overall Vehicle Performance Simulation and Analysis

4.1 Model Validation

The results of the single-motor centralized drive electric vehicle real vehicle test and the simulation results of the prototype are shown in Table 3.

Tab.3 Original vehicle test results and simulation results

Parameters	Original vehicle test data	Average value of test data	Simulation results
Maximum speed(km/h)	145 144 148 147 145	145.8	141.753

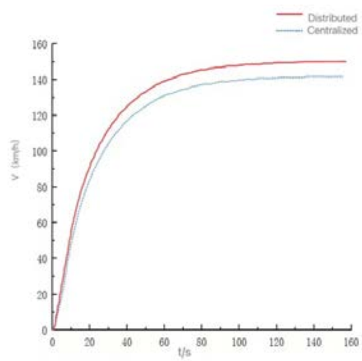
Max. climbing degree(%)	29 31 33 29 34	31.2	30.04
NEDC range(km)	176.3 177.4	176.9	178

The results of the Cruise simulation are obtained under ideal conditions, while the results of the real vehicle test are affected by various factors such as the external environment, which may cause errors, but the errors are small and within acceptable limits, thus verifying the correctness of the prototype model. The distributed drive electric vehicle model is evolved from the prototype model and is therefore also more accurate.

4.2 Performance Comparison Analysis

4.2.1 Power Performance

The maximum speed of the electric vehicle can visually reflect its power performance. From Fig. 3, the maximum speed of the distributed-drive can reach 150.6km/h, while the maximum speed of the single-motor centralized-drive is 141.753km/h. The climbing degree of the vehicle is also an important index to evaluate its power performance. From Figure 4, the climbing degree of both models is greater than 30%, which meets the initial design requirements. And the maximum climbing degree of distributed-drive electric vehicle can reach 33%, which is better than that of centralized-drive electric vehicle.



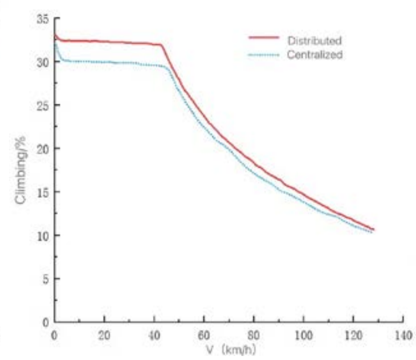
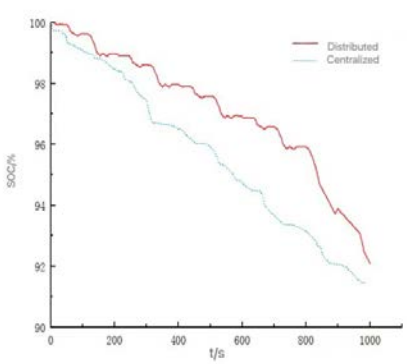


Fig.3 Time-Speed Curves Fig.4 Speed-Climbing Curves

4.2.2 Economic Performance

The SOC reflects the actual available power of the power battery, which is a very important indicator in the operation of electric vehicles and directly affects the range of the vehicle.

Figure.5 and figure.6 shows the SOC variation curves under NEDC and FTP75 operating conditions. From the figures, it can be seen that the distributed drive electric vehicle model eliminates the traditional transmission system, and the vehicle power is lost in the transmission process with less loss, high transmission efficiency and low power consumption.



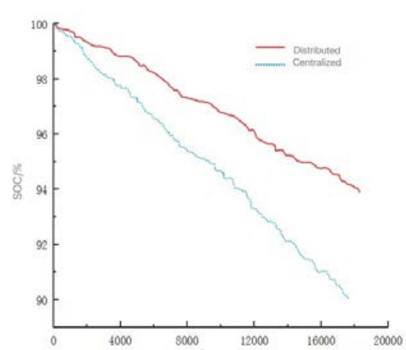


Fig.5 Time-Soc Curves Fig.6 Distance-Soc Curves

5. Conclusion

The simulation curves of the maximum speed and climbing performance show that the power performance of the distributed electric vehicle is better than that of the centralized electric vehicle. Through the comparison of parameter matching and simulation of distributed EVs, the rationality and advantages of distributed models are verified, which provides a basis for future research on the simulation of distributed EV control strategies, etc.

References

[1] Tong Gang, Dai Jiazhe, Xue Kuijv, Zhuang Jialiang. Design and simulation of HEV power system based on ADVISOR secondary development. Machine Design and Manufacture, no.12, pp.71-74+80, 2019.

[2] Xue Qicheng, Zhang Xin, Cui Yuxuan. Research on power system of four-wheel drive electric vehicle. Mechanical Science and Technology, vol.40, no.02, pp.287-295, 2021.

[3] Lv Chunchi. A review of the current status and trends of core technology development of new energy electric vehicles. Technology and Innovation, no.17, pp.80-81, 2020.

[4] Lu Yingpeng, Chang Jiahang, Jiang Meng. Drive control research of rear hub motor independent drive electric vehicle. Journal of Southwest Normal University(Natural Science Edition) , vol.39, no.04, pp.147-151, 2014.