Simulation of dynamic and economic performance of pure electric vehicle based on two speed automatic transmission

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Abstract. In order to study the influence of transmission matching on the power and economy of pure electric vehicle , The establishment of EQ5038XXYL pure electric van car model and simulate its power and mileage by using AVL cruise platform. On the basis of the original vehicle power transmission system, the automatic transmission with two gears and final drive are added. As a result, the dynamic performance and driving range have been improved to varying degrees . Power acceleration time decreased by 4% , Maximum climb slope increased by 11.3% , Maximum speed increased by 10.5% ; In terms of economy, the driving range increased by 7.3% .

Introduction

At present, the domestic and foreign pure electric vehicle manufacturers in the automotive power transmission system is also matched transmission.However, the fixed speed ratio transmission is not able to meet the needs of various conditions. In this paper, EQ5038XXYL pure electric van model as the research object ,which explores the influence of multi gear transmission on the power and economy of the pure electric vehicle . Because the motor's speed control characteristics is good, the gear reducer of the gear should not be too much, generally not more than three. Therefore, this article on the EQ5038XXYL pure electric van transportation vehicle power transmission system based on matching two gear automatic transmission and final drive.

At present, the software used for pure electric vehicle simulation is mainly:(1) MathWorks developed by MATLAB and its derivative software advisor; (2) Cruise software developed by Austria AVL company.The difference between cruise and advisor is that cruise can be seen as an upgraded version of advisor. AVL cruise has the ability to quickly model, to predict the power and economy of the vehicle, optimize the transmission coefficient . Therefore, this paper selects AVL cruise as a simulation tool to study the power and economy of the pure electric vehicle.

Transmission ratio design

Motor has such a characteristic: When the input power is certain, the speed is slower, the torque is higher;the higher the speed is, the lower the torque is;At this time the motor efficiency is the highest. Therefore, when the input power is certain, the motor will automatically adjust to the most efficient way to output power. The actual performance is when the car stops, you step on the accelerator pedal, because of the inertia of the resistance, the motor automatically adjust to the acceleration pedal you step can achieve the maximum torque, And then in the acceleration process, at each point in time, it is always automatically to reduce the torque in exchange for this time point of the highest speed, So the motor does not need the gearbox. With the gearbox, the car can be faster and is not possible. In the case of a certain input energy, it will only open more slowly, because some of the energy is wasted.

But the motor is not really complete without the need to add the gearbox, which depends on the application environment and design. Motor speed regulation characteristic better, deceleration device gear number should not be too much, there is generally no more than three stalls, which can reduce the cost and can avoid the deceleration and the volume and weight of the device is too large and reduce the efficiency of the transmission system, the impact of vehicle performance. Although the motor starting torque is large, but at this time the demand for the current is also the largest， High power output current is the test of battery and make rapid heat and even burn motor motor.In addition, the electric car starting current, low speed current, climbing weakness, speed, power consumption is too large and the output can not change with the changes in the torque caused by the motor, battery and controller of the serious damage . So in order not to improve the output power of the battery (of course, this is very difficult to improve), do not do special improvements to the motor, can not be designed to carry a higher current of the circuit board, and the gearbox should be the best way. But the transmission gear number should not be too much.In order to meet the requirements of power and economic , plus gearbox should be the best way.

（1）Upper limit of transmission ratio

The upper limit of the transmission ratio is determined by the maximum speed of the motor and the maximum running speed:

$$\sum_{\min} i \le \frac{0.377 \times n_{\max} \times r}{u_{\max}} = \frac{0.377 \times 3800 \times 0.32}{95} = 4.8 \tag{2.1}$$

（2）Lower limit of transmission ratio

The maximum output torque and the maximum climbing slope correspond to the running resistance to determine the lower limit of the transmission ratio of the transmission system:

$$\sum_{\max} \mathrm{i} \ge \frac{\mathrm{r}}{\eta_{\mathrm{t}} \cdot T_{\max}} \times (m \cdot g \cdot f \cdot \cos\alpha_{\max} + m \cdot g \cdot \sin\alpha_{\max} + \frac{C_D \cdot A \cdot \mathrm{u_f}^2}{21.15}) = \frac{0.32}{45\% \times 450} \times (3000 \times$$

$$9.8 \times 0.015 \times 0.9889 + 3000 \times 9.8 \times 0.148 + \frac{2.78 \times 0.45 \times 12^2}{21.15}) = 7.57 \tag{2.2}$$

Transmission ratio result as follows

Final drive ratio: 4

First Gear transmission speed ratio: 1.89

Second Gear transmission ratio: 1.2

Simulation of electric vehicle and analysis of simulation result

In the process of building a pure electric vehicle simulation model with AVL cruise software, the key is to establish the battery matrix model and the motor simulation model[1].

The establishment of power battery model

In the current stage, the electric car battery is mainly lithium-ion batteries. SOC is the most important parameter of Lithium- ion battery. SOC is not only related to temperature, but also related to the load current and duration of discharge. The specific relationship is as follows 2.1:

$$\mathrm{Q_u}(\mathrm{t}_0, i_a, t) = Q(t_0, i_a) - \int_0^t i_a(t)dt \tag{3.1}$$

$\mathrm{Q_u}(\mathrm{t}_0, i_a, t)$ is battery remaining capacity , t_0 is battery discharge temperature, i_a is battery discharge current ,t is continuous discharge time , $Q(t_0, i_a)$ is total battery capacity , $\int_0^t i_a(t)dt$ is total output current from 0 to t.

The analytical expression of the internal resistance of the battery is as follows 2.2:

$$R(i_a, t_0, Q) = R_{el}(t_0, Q) + R_e(Q) + bE(k)i_a^{-1}(t) \tag{3.2}$$

$R_{el}(t_0, Q)$ is electrolyte resistance, $R_e(Q)$ is electrode resistance, $bE(k)i_a^{-1}(t)$ is polarization resistance,b is terminal voltage variation coefficient,E(k) is instantaneous electromotive force of battery.

Battery model can be equivalent to a series of simple electromotive force and internal resistance, so the battery terminal voltage can be calculated by the following 2.3:

$$u(t,k) = E(t_0, k) - i_a(t)R(i_a, t_0, Q) \tag{3.3}$$

$E(t_0, k)$ is t time battery electromotive force, $R(i_a, t_0, Q)$ is t time battery internal resistance.

The establishment of driving motor model

In this paper, EQ5038XXYL pure electric van is used in permanent magnet synchronous motor. The flux equation of permanent magnet synchronous motor is:

$$\begin{cases} \varphi_q = L_q I_q \\ \varphi_d = L_d I_d + \varphi_r \end{cases} \tag{3.4}$$

φ_q、φ_d、φ_r is magnet flux linkage produced by permanent magnet of rotor; L_d、L_q is stator equivalent inductance. For permanent magnet synchronous motor, $L_d = L_q = L$.

The electromagnetic torque T_e can be expressed as:

$$T_e = P(\varphi_d i_q - \varphi_q i_d) = P[\varphi_r i_q + (L_d - L_q) i_d i_q] \tag{3.5}$$

P is motor pole pairs, i_q、i_d is stator current，$\varphi_d i_q$ is permanent magnet torque, $\varphi_q i_d$ is the reluctance torque caused by the asymmetry of rotor.

The equations of motion of the motor can be expressed as：

$$T_e - T_1 - B\omega_r = \frac{J}{P} \times \frac{dw_r}{dt} \tag{3.6}$$

T_1 is motor load torque,B is damping coefficient of electric machine,J is motor moment of inertia, ω_r is rotary angular velocity of motor rotor

Simulation of vehicle model

On the basis of the electric car with 2 gear automatic transmission and the final drive, The vehicle simulation model of electric vehicle is shown in Fig.1.

Including battery module, motor module, transmission module, the main reducer module, the differential module, the brake module, the wheel module, vehicle parameters module, driver module and monitoring module . The partial parameters of each module are shown in Table 1.

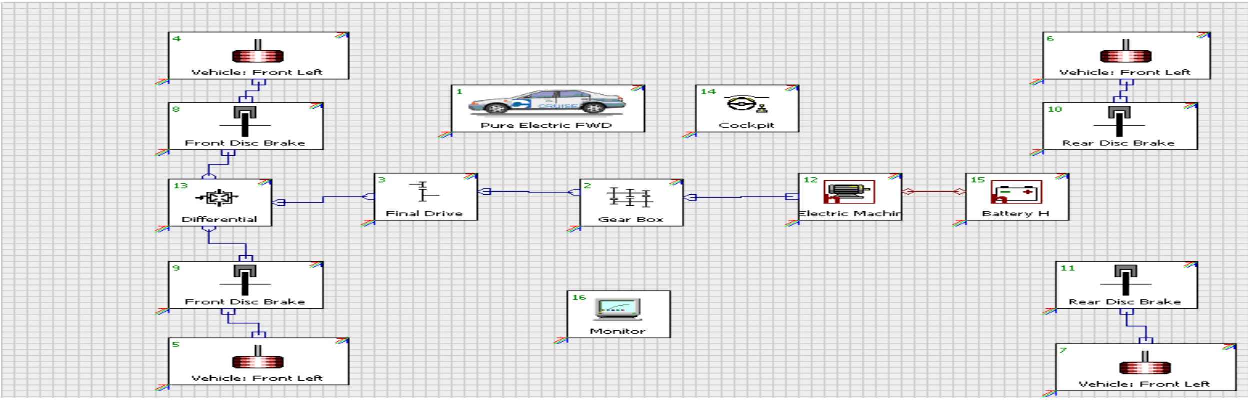


Fig.1. The vehicle simulation model of electric vehicle

Table1 parameter input

parameter	Value
Wheel base	3000
Curb/Gross weight	2160/3000
No-load/Half-load/full-load centroid height	784/862.4/921.2
No-load/Half-load/full-load distance of gravity of center	1583/1651/1700
Frontal Area	2.78
Drag Cofficient	0.45
Lift Coefficient FrontAxle/Rear Axle	0.032/0.017
Inertia Moment（kg*m2）	0.38
Static Rolling Radius	305
Dynamic Rolling Radius	320
Rolling Friction Coefficient	0.015
Transmission file number	2
Total reduction ratio	7.57/4.8
Efficiency of transmission system	0.98
Front / rear brake master cylinder surface area	1850/1560
Effective friction radius of front / rear brake （mm）	135/115
Brake friction coefficient	0.25
Brake efficiency	98%
Weight of single cell （kg）	2.1
Energy density（Wh/kg）	152.4
Nominal battery voltage （V）	3.2
Single cell charging cut-off voltage （V）	3.7
Single cell discharge cut-off voltage （V）	2.1
Nominal capacity of single cell （Ah）	100
Motor quality （kg ）	115
Rated voltage（V）	384
Power rating（kW）	45
Peak power（kW）	60
Rating torque（Nm）	337.5
Peak torque（Nm）	450
Rated speed（r/min）	1273
Maximum speed（r/min）	3800

Analysis of simulation result

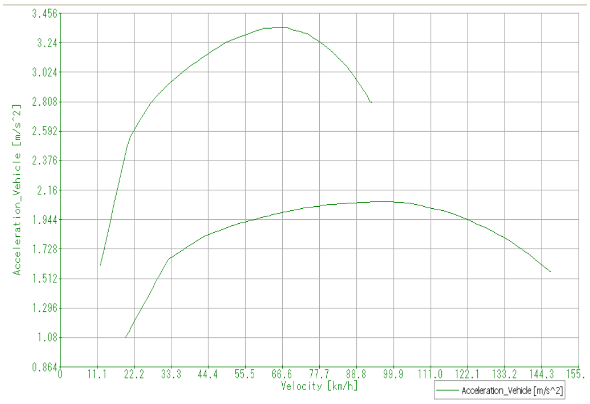
(1) Dynamic analysis

This section is mainly aimed at the acceleration time of the electric vehicle, which is shown in Fig.2;the maximum climbing slope, which is shown in Fig.3;the maximum speed and other simulation results are analyzed,such as Cruise running, which is shown in Fig.4.The simulation results are as follows , It can be seen that the matching of the acceleration time, the maximum climb slope, the maximum speed than before the match has been better improved , It is precisely because of the structure of the matching drive system makes the transmission ratio is more extensive, so that the performance of the dynamic performance than before the match is improved, which shows that the motor and the transmission system match is more appropriate.In addition, Battery voltage change curve with SOC and Motor power speed curve are separated showed in Fig.5 and Fig.6.

Dynamic performance simulation results is shown in Table 2

Table 2 Dynamic performance simulation results

Test item	Before matching	After matching
0~50km/h acceleration time (s)	10s	9.6
maximum gradability (%)	10	11.3
maximum speed（km/h）	95	105



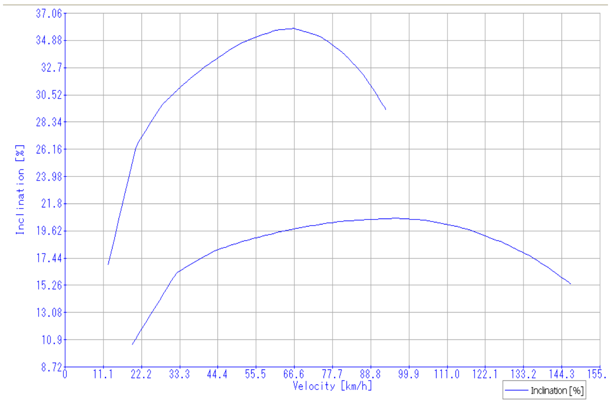


Fig.2. Simulation of full load acceleration performance

Fig.3 Simulation of full load climbing performance

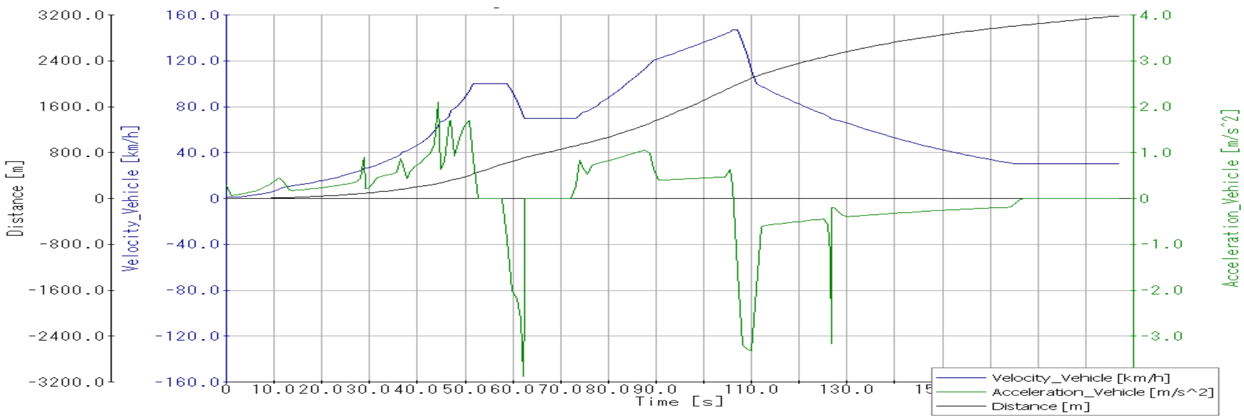
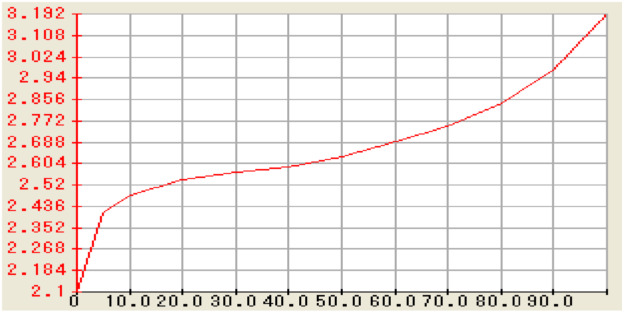


Fig.4 Cruise simulation



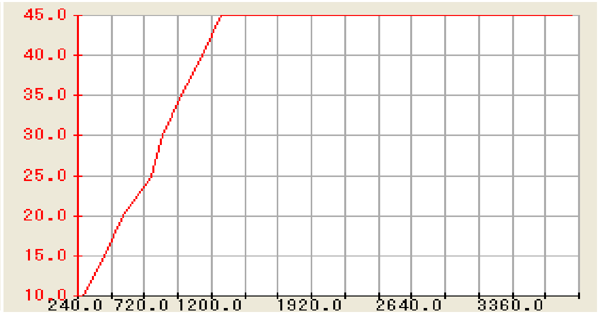


Fig.5 Battery voltage change curve with SOC   Fig.6 Motor power speed curve

(2) Economic simulation result analysis

In this paper, the simulation conditions are used to calculate the UDC of urban working conditions,

The detailed calculation results are shown in table 3

Seen from the following table, the number of driving range of electric vehicles has increased. This is mainly to match the two gear automatic transmission, the motor is in a more efficient work, energy loss is smaller.

Table 3 Economic simulation results

Test item	Before matching	After matching
Driving range （km）	174	186.7

UDC simulation conditions is shown in Fig.7. With the continuation of the simulation time, SOC is gradually reduced, but there is no mutation. From this, we can know that the motor and the battery to meet the UDC (urban conditions) driving requirements, the power system parameters match the correct, reasonable.

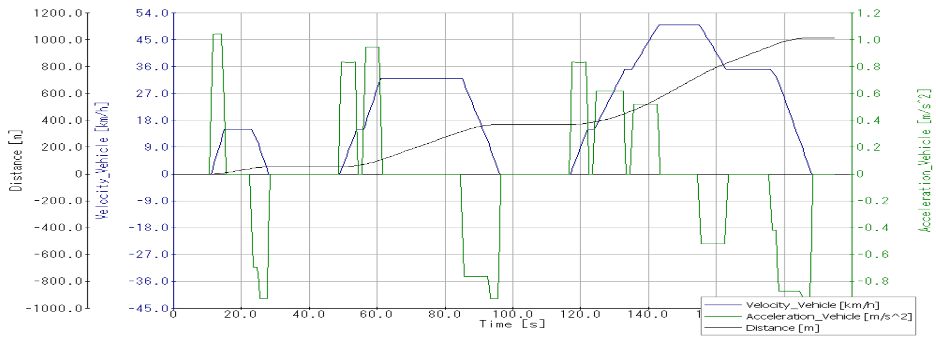


Fig.7.UDC simulation condition of city cycle

In this chapter, we establish the simulation model of pure electric vehicle powertrain system. After inputting the parameters of the vehicle and setting the calculation task, the simulation is done. Finally, the dynamic performance and the driving range simulation results are analyzed,and the rationality of the dynamic matching is verified.

conclusion

Based on the EQ5038XXYL for pure electric van , Power and economic indicators, on the basis of original power transmission system by loading two speed automatic transmission and final drive,the vehicle power and economy based on the basis of the original car got different degrees of improvement. The results show that the transmission system can improve the working efficiency of the motor and the driving range of the motor can be improved by matching the transmission and final drive. By matching the deceleration transmission device, making the vehicle power, mainly including the acceleration time, maximum speed, climb the slope have been improved.

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