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The development of a battery electric car

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Abstract
In order to respond to the call of national policies related to the new energy automobiles, the project of a battery electric car(EV) development has been implementing by electric vehicle research institute of Tsinghua university, Yangzhou Jinfeichi electric vehicle Co. Ltd and Lifan industry company since September 2008. After six months of hard works, the main task including parameters matching, vehicle assembly and test have been completed. In the EV, the front-wheel drive form is adopted, a Li-ion battery pack is used, and the powertrain is composed of permanent magnet(PM) motor and a two -gear transmission. Based on MATLAB/Simulink software, a simulation model that can calculate the EV performance is devised. For the sake of meeting the performance requirements, the parameters of motor and battery pack are selected, and the gear ratios are also optimized. Furthermore, the software and hardware of the vehicle controller unit(VCU) are designed based on V-cycle process. Finally, the dynamic and economic performance of the EV are inspected, and all performance indexes can satisfy the requeirements.

Keywords: Battery electric vehicle , parameters matching, components design, assembly and test

1 Introduction

During the 2008 Beijing Olympic Games, more than 500 electric vehicles had been used as the transport fleet, which played an important role in realizing the pledge of Green Olympic Games. Now, many Chinese people have accepted the fact that the application of new energy automobiles can greatly reduce air pollution in major cities, as well as to alleviate the oil shortage.
It is reported that China will speed up the development of electric vehicles, the support plan that an individual EV car buyer can get 60,000 yuan subsidy from government's new energy promotion program has been implementing since February 2009 [1].
In order to respond to the call of developing the new energy automobiles, the project of a battery electric vehicle (EV) development has been implementing by electric vehicle research institute of Tsinghua university, Yangzhou Jinfeichi electric vehicle company and Lifan industry company since 2008. Now, some basic works including parameters matching, vehicle assembly and test have been completed.

2 Configuration and performance target

The schematic structure of the EV is shown in figure 1. In the EV, the front-wheel drive form is adopted, a Li-ion battery made in china is used, and the powertrain is composed of permanent magnet (PM) motor and a transmission which has two gears, the first gear is utilized to increase the grade ability and acceleration ability, but the second gear is always used except for the starting and climbing condition. At present, the gearbox is manually shifted, however, the gear will be changed automatically in the second phase of the study, which eliminate the need for the driver to operate the clutch and manually shift gear.

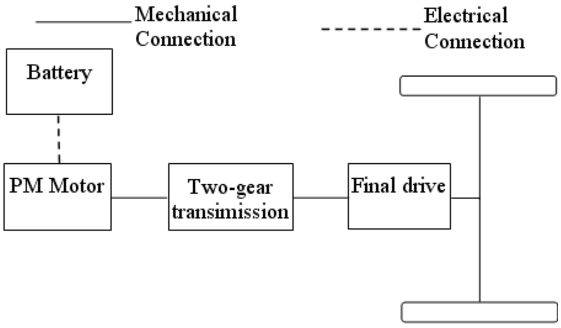

Figure 1: The schematic structure of the EV

The basic parameters of the EV can be seen in table 1.

Table 1: Basic parameters of the EV

Kerb mass (kg)	Wheel radius (m)	Frontal area (m^2)
1100	0.283	2.5
Air drag coefficient	Rolling resistance coefficient	Final drive ratio
0.3	0.015	3.941

The performance requirements of the EV is shown in table 2, besides those, the maximum noise outside car must be less than 3 dB(A) when the EV is in acceleration condition, furthermore, battery charge speed, vehicle safety and electromagnetic compatibility should meet the related national standards.

Table 2: Performance requirements

Dynamic performance	Maximum speed（km/h）	≥100
	0~50 (km/h) acceleration time (s)	≤8
	0~80(km/h) acceleration time (s)	≤18
	Maximum gradeability（%）	≥30
Economic performance	Energy consumption（kWh/100km）	≤10
	Continued driving mileage（km）	≥120

3 Parameters matching

3.1 Simulation model

Based on MATLAB/Simulink software, a simulation model that can calculate the EV performance indexes including maximum speed, acceleration time and gradeability is devised, which can help to select the parameters of the motor and transmission. The interface of the simulation model can be seen in figure 2.

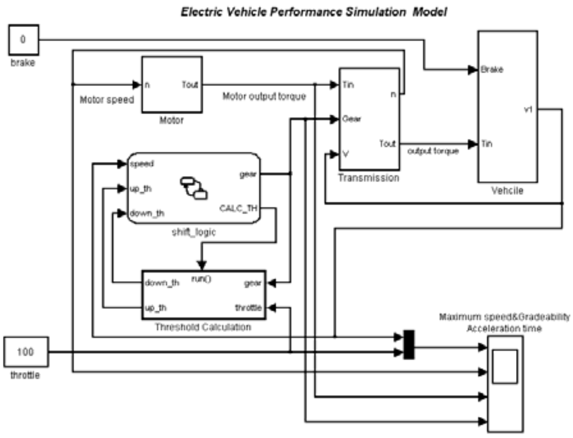

Figure 2: Interface of the simulation model

3.2 Motor parameters

In order to achieve the maximum speed, the peak power must satisfy the following inequality

$$P_{max} \geq (mgfv_{max}/3600 + C_D A v_{max}^3/76140)/\eta \qquad (1)$$

where P_{max} is peak power of the motor, m is the half load mass whose value is 1250 kilograms, f is the rolling resistance coefficient, v_{max} is the target of the maximum speed, η is the efficiency of the powertrain whose value is 0.9, C_D is the air drag Coefficient and A is the frontal area.

The peak torque curve of the motor is difficult to determine by the formula. Based on the constraint of the calculated peak power, some motors are selected, and the corresponding acceleration time is tested by the simulation model. The fact that the parameters of the motor have a greater impact than gear ratios is observed, so a fixed pair of gear ratios is firstly adopted during the selection of the peak torque curve. After repetitive calculation, the adopted motor parameters are shown in table 3.

Table 3: Parameters of the PM motor

Rated power (kW)	Rated torque (Nm)	Rated speed (r/min)
15	57	2500
Maximum power (kW)	Maximum torque (Nm)	Maximum speed (r/min)
40	220	5000

3.3 Gear ratios

The gear ratios are determined by two steps. First, the numerical range of the first and second gear ratio are calculated according to the requirements of the maximum speed and gradeability, then, the acceleration time at different ratio combinations are calculated by the simulation model, in the third step, the two-gear transmission whose dynamic and economic performance are better and can be provided by the supplier is adopted.

In order to meet the maximum gradeabiliy, the range of the first gear ratio should satisfy the following inequality

$$i_1 \geq (mgf\cos\alpha + mg\sin\alpha) r / T_{max} / i_0 \eta \quad (2)$$

where i_1 is the first gear ratio, T_{max} is maximum torque of the motor, α is gradeability index whose value is 16.75 degrees, r is wheel radius and i_0 is gear ratio of the final drive.

The calculated i_1 range is denoted as the inequality (3).

$$i_1 \geq 1.35 \quad (3)$$

The range of the second gear ratio is calculated by inequality (4) and (5) [2], which guarantee the EV can get the maximum speed and ensure the motor power lies in the peak point when the EV run at the maximum speed.

$$i_2 \leq 0.377 r n_{max} / v_{max} / i_0 \quad (4)$$

$$i_2 \geq 0.377 r n_{ep} / v_{max} / i_0 \quad (5)$$

where i_2 is the second gear ratio, n_{max} is the maximum speed of the motor, n_{ep} is the rotating speed at which motor can output the peak power and whose value is 2800 r/min.

The calculated i_2 range is shown as inequality (6) .

$$0.76 \leq i_2 \leq 1.3 \quad (6)$$

At the scope of the inequality (3) and (6), how the acceleration time is influenced by the gear ratios when the EV accelerate to 50 and 80 kilometers per hour, are shown in figure 3 and 4 respectively, which demonstrate that the first gear ratio have a greater influence than the second gear ratio.

Except for the starting and climbing condition, the second gear is always used, so the second ratio also influence the load efficencey of the motor. In general, the smaller the second ratio is, the better economic performance can get, but the interval between the first and the second gear ratio should not be too large, or which will deteriorate the shift quality.

Finally, Considering the transmissions can be selected, the best ratios of the first gear and second gear should be 1.71 and 1.0294.

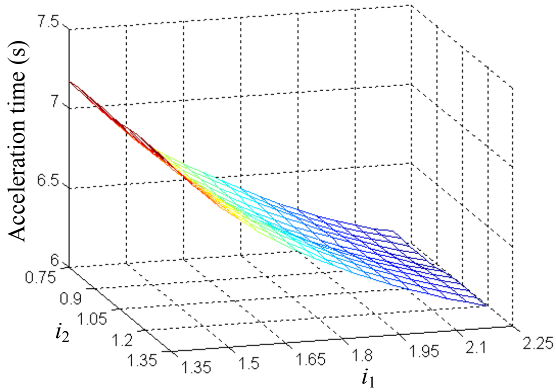

Figure 3: 0~50 (km/h) acceleration times at different gear ratios

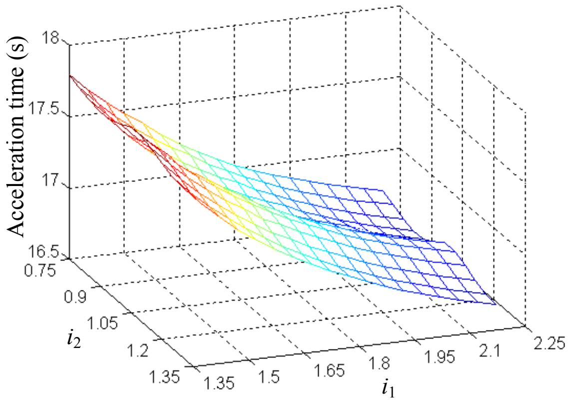

Figure 4: 0~80 (km/h) acceleration times at different gear ratios

3.4 Battery pack parameters and cell characteristic

The design goal of the continued driving mileage, when the EV travels at a constant speed (60 kilometres per hour), is more than 120 kilometres.

Taking into account the efficiency of the motor and the battery, the available energy releasing from battery pack should be greater than 16 kWh, therefore, the rated voltage and capacity of the battery pack we determined are 320 V and 50 Ah respectively . The battery pack is composed of 100 cells in the form of series.

The performance of a LiFePO4-based Li-ion and a Ni-MH battery are tested, which are all made in China. The aspects of the experimental evaluation include rated voltage, available capacity, available energy, internal resistance, efficiency, heat generation and self-discharge. The research indicates that LiFePO4-based Li-ion battery has better performance, so it is used; whose main characteristics including cell open circuit voltage and internal resistance are show in figure 5 and figure 6.

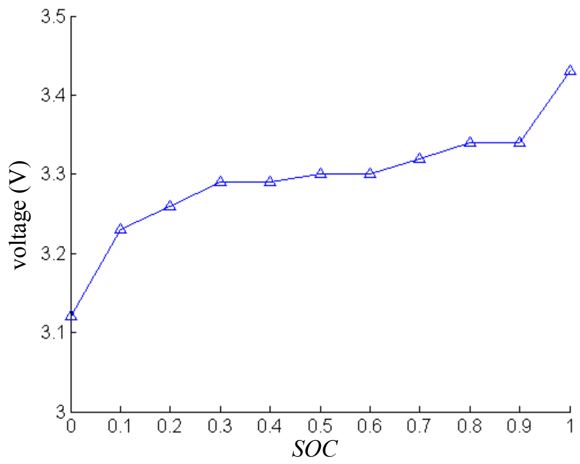

Figure 5: Battery cell open circuit voltage curve

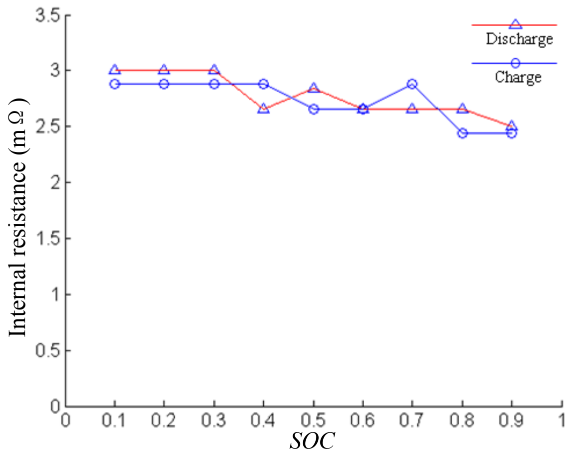

Figure 6: Discharge and charge internal resistance

4 The vehicle controller unit

The vehicle controller unit(VCU) is also designed based on V-cycle development process , VCU hardware is composed of microcontroller, power supply module, CAN bus communication module, input signal and output signal channels, as shown in figure 7.

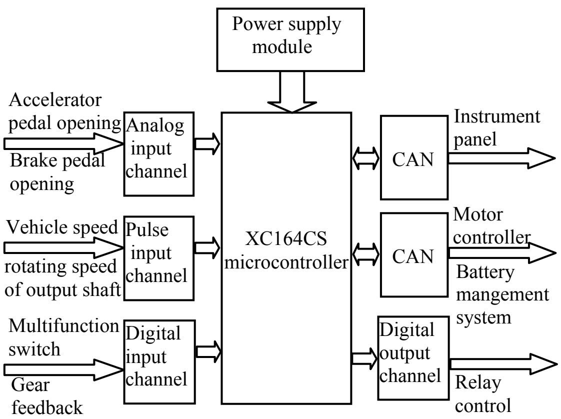

Figure 7: Block diagram of the VCU hardware

In the hardare, XC164CS singlechip is used as central processing unit (CPU). Analog input channel, digital input signal channel, pulse input signal channel and digital output signal are designed according to the types of input and output signals.

Furthermore, the communication module of the Controller Area Network (CAN), which is composed of CAN controller, transceiver and electric insulation module, is also designed. In order to improve Electromagnetic Compatibility of the controller, filter circuit is adopted in pulse input channel.

Moreover, photo electricity insulation technology is used in digital input channel, digital output channel and CAN communication module, which can reduce I/O channel disturbance.

In the VCU, Analog input signals include accelerator pedal and brake pedal, pulse input signals consist of vehicle speed and rotating speed of output shaft, digital input signals are composed of multifunction switch and the gear feedback, digital output channel is used to control the relay. The CAN is utilized to communicate the VCU with the motor controller, battery manangement system and the instrument panel.

The VCU hardware can be seen in figure 8.

Figure 8: VCU hardware

5 EV layout

According to the layout of the Lifan 520 car, the motor and two-gear transmission assembly is mounted at the position where the internal combustion engine and transmission were originally installed; the motor controller is fixed on the top of the motor.

The battery pack is divided into five boxes, three boxes are laied in the car trunk, the other boxes are installed in the former layout.

The layout of the former cabin and car trunk are shown in figure 9 and figure 10.

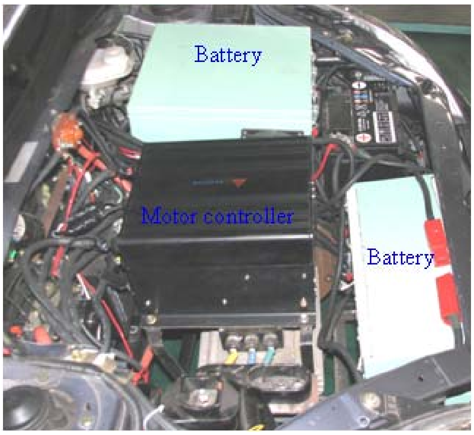

Figure 9: the layout of the former cabin

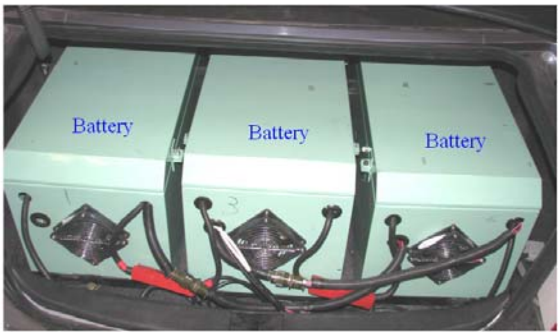

Figure 10: The layout of the car trunk

6 Conclusion and prospect

Finally, the dynamic and economic performance of the EV are inspected, and all performance indexes satisfy the requirements.

In addition to the above works, a new type EV chassis is developing, which can optimize the layout of the various components, we expect it can further improve the EV performance.

Acknowledgments

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