Parameter matching and simulation analysis of power system of pure electric vehicle

Jiwei Geng*a, Qun Chi*b*
Nantong Institute of Technology, Nantong, China, 226000
*a*2538285743@qq.com, b*794822573@qq.com

Abstract—The consumption of gasoline and diesel for cars is beyond imagination. Along with these problems comes environmental destruction. In order to achieve the two major indicators of power performance and economy, the most critical component of electric vehicles --- the power system is optimized and improved, and simulation is used to verify it on this basis. It can be concluded that the maximum vehicle speed is greater than 120km/h, the maximum gradeability exceeds 30%, the cruising range reaches 178km.

1. Introduction
The car’s energy consumption is astonishingly large[1]. Considering environmental protection and other issues, the power sources of cars have become diversified[2]. Although, in recent years, new energy vehicles have come into people's vision[3], especially pure electric vehicles have attracted much attention. It's just that there are still many technical problems[4]. Therefore, it is of profound significance to design and match the power system parameters of pure electric vehicles.

In order to solve the problems of electric vehicles in terms of power and endurance, the main power system is redesigned to determine the rationality of the parameters. On this basis, AVL-Cruise is used for simulation to obtain high-efficiency indicators.

2. Main parameters matching and design

2.1. Vehicle performance index
This study is based on vehicle parameters and basic performance indexes (as shown in Tables 1 and 2) to ensure that it meets the dual requirements of power and economy.

| Reference | Reference value | Unit  |
|-----------|-----------------|-------|
| length*width*height | 4620*1820*1515 | mm    |
| Curb weight | 1515 | kg |
| Wheelbase | 2680 | mm |
| Total weight | 1900 | kg |
| Windward area | 2.16 | mm² |
| Coefficient of air resistance | 0.3 |   |
| Wheel rolling radius | 307 | mm |
| Total drive system efficiency | 0.95 |   |
| Rotation mass conversion factor | 1.04 |   |
| Rolling drag coefficient | 0.011 |   |
| Centroid distance from front axis | 1200 | mm |
| Center of mass distance from rear axis | 1480 | mm |

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| Dynamic performance parameter | unit | indicators |
|-------------------------------|------|------------|
| acceleration | s | 0-50km/h ≤5 |
|  |  | 50-80km/h ≤5 |
|  |  | 0-100km/h ≤12 |
| Top speed | Km/h | 120 |
| Maximum climbing slope (20km/h) | % | 30 |
| range (60km/h) | km | 160 |

2.2. Drive motor matching

The driving motor is the core component of the power system, which directly affects the power performance of the vehicle[5].

2.2.1. Calculation of the rated power of the drive motor

Many problems should be considered in this design, such as the need to ensure the maximum speed of the pure electric vehicle to select the power of the drive motor, its power consumption is expressed as follows:

\[ P_N = \frac{1}{3600 \eta_1} \left( mgf + \frac{C_D A U_{\text{max}}^2}{21.15} \right) U_{\text{max}} \]  

(1)

In the above formula, \( P_N \) represents the rated power of the drive motor (kW); \( m \) represents the mass of the vehicle (kg), the value is 1515kg; \( f \) is the rolling friction coefficient, the value is 0.011; \( C_D \) represents the air resistance coefficient, the value is 0.3; \( A \) is the windward area of the vehicle (m²), the value is 2.16; \( \eta_1 \) stands for mechanical efficiency, the value is 0.81; \( U_{\text{max}} \) stands for maximum speed (km/h), the value is 120km/h. Substitute into the above formula, \( P_N = 25.01 \text{kw} \).

2.2.2. Determine the peak power of the engine

During the acceleration of a pure electric vehicle, the speed can be expressed by the following formula:

\[ u = u_m \left( \frac{t}{t_m} \right)^x \]  

(2)

In equation (2) above, \( u_m \) represents the time of the car’s final acceleration, \( t_m \) is the acceleration time of a car, and \( x \) is a fitting coefficient, the value is 0.5.

When the car accelerates, it will be affected by acceleration resistance, rolling resistance and air resistance. Its instantaneous power can be expressed as:

\[ P_{\text{max}2} = \left( Gf + \delta m \frac{u_m^2}{2 \sqrt{t_a}} + \frac{C_D A u_m^3}{21.15 \times 2.5} \right) \frac{1}{3600 \eta_1} \]  

(3)

Substituting formula (2) into (3) to simplify and get the following expression:

\[ P_{\text{max}2} = \left( Gf + \delta m \frac{u_m^2}{2 \sqrt{t_a}} + \frac{Gf u_m t_a}{1.5} + \frac{C_D A u_m^3}{21.15 \times 2.5} t_a \right) \frac{1}{3600 \eta_1 t_a} \]  

(4)

In the above formula, \( t_a \) represents the acceleration time of the car and \( u_m \) represents the speed of the car after acceleration.

Substitute the parameters of the pure electric vehicle and the whole vehicle's dynamic performance
index into (4), it can be calculated that the peak power of the motor when the vehicle accelerates to 120km/h is 85.57kW, which can be 90kW.

The relationship between the maximum power of driving the generator and the rated power can be expressed by the following formula:

\[ P_e = \frac{P_{\text{max}}}{\lambda} \]  

(5)

In formula (5) above, \( P_e \) refers to the rated power of the drive motor, \( \lambda \) refers to the overload factor of the car, which can be valued at either 2 or 3. \( P_e = 45 \text{kw}. \)

| Table 3 Parameters of the drive motor |
|--------------------------------------|
| Motor type                           | Permanent magnet synchronous motor | The highest speed | 7500r/min |
| Rated speed                          | 2500r/min                           | Rated torque      | 175Nm     |
| Rated voltage                        | 320V                                | Peak torque       | 350Nm     |
| Rated power                          | 45kW                                | size              | 300*190*190 |
| Peak power                           | 90kW                                |                   |           |

2.3. Power battery matching

There are many types of batteries used in electric vehicles, and they can be selected reasonably according to different characteristics and needs.[6-7]

| Table 4 Drive motor parameter selection |
|-----------------------------------------|
| Nominal battery capacity                | 10Ah                                  | Battery Type     | Lithium iron phosphate battery |
| Battery internal resistance             | 30-80mΎΩ                             | Single voltage   | 3.2-3.65V                      |
| Total voltage                          | 320V                                 | Number of batteries | 11*100                      |
| General charging current                | 0.2-0.5C                              | combination      | parallel                       |

3. Vehicle modeling and simulation analysis

3.1. Building a vehicle module

![Fig.1 Full-vehicle model of pure electric vehicle](image)
3.2. Vehicle simulation results

3.2.1. Dynamic performance analysis

(1) Maximum climbing slope

It can be clearly seen from the figure below that the maximum slope of the pure electric vehicle is 35% (as shown in fig.2: relationship between gradeability and speed), and the maximum Angle of the vehicle is 34.36% at the required speed of 20km/h, which basically meets the design requirements and verifies the rationality of the vehicle’s dynamic performance.

![Fig.2 Maximum gradeability simulation curve](image)

| Gear | Max. Inclination | Velocity (km/h) | Speed (1/min) | Speed Ratio |
|------|------------------|----------------|---------------|-------------|
| 1    | 34.36            | 3.00           | 160.10        | 0.00        |

![Fig.3 Maximum gradeability simulation data](image)

(2) Top speed

In the simulation design process, when the pure electric vehicle is fully loaded, the maximum speed of the vehicle is 120km/h. Through actual simulation, the maximum speed of the vehicle is 175km/h, which fully meets the expected requirements and can verify the rationality of the vehicle's dynamic performance. As shown in Figure 4.

![Fig.4 Maximum speed performance simulation data](image)
3.2.2. Economic performance index

It can be seen from the figure that the maximum driving range of the vehicle is 178.67Km, which meets the designed maximum driving range of 160km, which can verify its economic performance at constant speed.

![Fig.5 Maximum cruising range for vehicles traveling at a constant speed of 60km/h](image)

4. Conclusion

In this paper, according to the power performance and economic indicators of the vehicle requirements, the motor, power battery and other key components of the power system matching calculation and design. Related design parameters were simulated by CRUISE, a professional automotive simulation software, and the following conclusions are obtained:

1) The simulation results show that the dynamic matching design is reasonable;
2) It is precisely because the results of this matching design can meet the requirements of power and economic indicators, it can not only bring substantial help to the development of pure electric vehicles, but also provide a theoretical basis for the optimization of power for other types of new energy vehicles;
3) This research only performed preliminary optimization of the power system. In the future, other main components can be reasonably designed and improved. If the performance of new energy vehicles meets the demand, the vehicle can also be tested in the future, in order to get better results.

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