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Retraction

Retracted: Study on Global Parameters Optimization of Dual-Drive Powertrain System of Pure Electric Vehicle Based on Multiple Condition Computer Simulation

Complexity

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] Y. Wang, H. Cai, Y. Liao, and J. Gao, "Study on Global Parameters Optimization of Dual-Drive Powertrain System of Pure Electric Vehicle Based on Multiple Condition Computer Simulation," *Complexity*, vol. 2020, Article ID 6057870, 10 pages, 2020.

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Research Article

Study on Global Parameters Optimization of Dual-Drive Powertrain System of Pure Electric Vehicle Based on Multiple Condition Computer Simulation

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Equipped with two power sources, the dual-driving powertrain system for pure electric vehicles has a driving mode different from traditional electric vehicles. Under the premise that the structural form of the transmission system remains unchanged, the following transmission schemes can be adopted for double drive electric vehicles according to the demand power: the main and auxiliary electric transmission scheme (two motors are driven separately with dual-motor coupling drive), the transmission scheme in which the two motors always maintain coupling drive, and the speed-regulating type electric transmission scheme (the main motor is always responsible for driving, and the auxiliary motor is responsible for speed regulation). Therefore, a significant difference exists in the design methods of the power transmission system of double drive electric vehicles and existing vehicles. As for such differences, this paper adopts intelligent algorithm to design the parameters of the transmission system and introduces the genetic algorithm into the optimization design of parameters to obtain the optimal vital parameters of the power transmission system based on computer simulation. The prototype car used in this paper is a self-owned brand car; MATLAB/Simulink platform is used to build the vehicle simulation model, which is used for the computer simulation analysis of the vehicle dynamic performance and economy. It can be seen from the analysis result that the system parameters obtained by using the global optimization method proposed in this study can improve the vehicle dynamic performance and economic performance to varying degrees, which proves the efficiency and feasibility of the optimization method.

1. Introduction

The rapid development and popularization of pure electric vehicles cannot be realized due to their high price, imperfect charging facilities, and low driving mileage. Although the problems of high cost and incomplete charging facilities have been improved to some extent due to the relevant policies of the government and the electric vehicle technology has also achieved significant development, the critical problem which hinders the development of pure electric vehicles, namely, "how to further improve the vehicle driving mileage," still exists. The driving mileage depends on battery technology (to improve battery power density and energy density); also, it is closely related to other factors, such as the configuration, parameter matching, and control method of the power transmission system [1–3]. Therefore, the key to improving the driving mileage and overall performance of pure electric vehicles lie in the efficient transmission system and its design method and the perfect energy control method [4–6].

Professor Zhao adopted genetic algorithm to conduct the optimization design by computer simulation of parameters for the power transmission system of a pure electric vehicle. The dynamic performance index was used as a constraint, and the weighting coefficient was used to transform the multiobjective optimization of driving mileage and vehicle mass into a single-objective optimization problem. The results were compared with the results obtained by the traditional optimization method. It could be seen from the comparison results that the optimization method could achieve the optimization design in an effective way [7–11]. Professor Zhou adopted two matching optimization methods (minimal kerb mass and global optimization methods) to optimize the power system parameters of the target vehicle and conducted the simulation comparison and verification of the vehicle dynamic performance and economic performance for the optimization matching effects. It could be seen from the results that the global optimization method was a more effective method, which could fully reflect the potential of parameter optimization matching of the power system in improving the vehicle performance [12]. Sorniotti et al. and other scholars used the configuration of single-motor pure electric vehicle proposed by them as the basis to carry out the optimal matching calculation of transmission system parameters. They designed the parameters for two-gear transmission and compared them with those of continuously variable transmission vehicles. The results proved that the optimal matching scheme was feasible and effective [13]. Professor Zhu and other scholars adopted the method of orthogonal optimization design based on a cycle condition to carry out the optimizing calculation for the two-speed transmission ratio of pure electric vehicles. Through the simulation results, it could be seen that the dynamic performance could be significantly improved by the transmission system parameters optimized and matched by this method. Still, its economic performance had declined [14]. Professor Kowal and other scholars and Professor Spichartz and other scholars had established the optimization model for the parameter matching of power transmission system of electric vehicles and the control model for the dynamic response property of the power system, which have achieved excellent results [15, 16].

In this research, the new configuration of dual-driving powertrain system for pure electric vehicles is taken as the research goal. Based on the analysis of its working characteristics and working mode, the vehicle performance computer simulation platform is established, and the preliminary matching of power transmission system parameters is completed by computer simulation, to prove whether the initial matching is reasonable; to improve the vehicle performance, the multiobjective optimization function (including the dynamic index and economic index) is determined in this paper, and the genetic algorithm is used to optimize system parameters based on computer simulation.

2. Overall Structure and Working Principle of the Dual-Driving Powertrain System for Pure Electric Vehicles

The design goal of this paper is a new configuration of dual-driving powertrain system for pure electric vehicles based on the planetary gear mechanism power coupling function. The engagement elements such as clutch and brake are used to achieve perfect working mode and the flexible switching between working modes, as shown in Figure 1.

The system consists of the following parts: one set of a single-row planetary gear mechanism, two motors (motor A; motor B), two wet brakes (B1; B2), and a wet clutch C; it outputs power through the planetary gear coupling device. The sun gear *s* of the single-row planetary gear mechanism is directly connected to the output shaft of motor B; the gear ring *r* is connected to the output shaft of motor A through the transmission gear *d*; the planet carrier *c* is connected to the driving axle through gear *e* for power output; the gear ring *r* can be connected to the sun gear *s* through clutch C; the movable part of brake B1 is connected to the box, and the fixed part of brake B1 is fixed to the output shaft of motor A; the gear ring *c* can be braked through brake B1. The movable part of brake B2 is connected to the box, the fixed part of brake B2 is fixed to the output shaft of motor B, and the sun gear *s* can be braked by brake B2 [17].

The dual-driving powertrain system for pure electric vehicles belongs to the category of multipower source. In addition to being used as a mechanical power source to drive the vehicle, motor A and motor B can also be used as electric power sources, which can operate as a generator during braking. When the parking brake is required, all motors are closed, all brakes operate, and the clutch is disengaged, thus complying with the parking requirements of the vehicle; when the vehicle needs to be kept in neutral, double motors are closed, and then the brake and clutch are all disengaged; during the starting stage of the vehicle and when the vehicle is running at low- and medium-speed and small-load demands, motor A is driven separately, brake B2 operates, the sun gear is locked, and the power of motor A is input through the transmission gear and output through the planet carrier, thus realizing the small-speed ratio deceleration output and complying with the low and medium torque demands of the vehicle; when the vehicle is running at low-speed and large-load demands, motor B is driven separately, brake B1 operates, the transmission gear is locked, thus the gear ring is locked, and the power of motor B is input through the sun gear and then output through the planet carrier, thus realizing the large-speed ratio deceleration output and complying with the large torque demands of the vehicle; when the vehicle is running at high- and medium-speed and medium- and small-load demands, all brakes and clutches are disengaged, the planetary gear mechanism is unlocked, and the planetary mechanism is used to achieve the speed coupling between motor A and motor B, thus jointly driving the vehicle and realizing the continuously variable speed; when the vehicle is running at medium-speed and large-load demands, all brakes are disengaged, the clutch is engaged, the planetary gear mechanism is locked to form a entirety, and the torque coupling between motor A and motor B is realized to jointly drive the vehicle; during vehicle deceleration, the status of both brakes is controlled to determine whether the regenerative braking is performed by motor A or motor B. During the whole mode switching period, the motor can ensure that the sun gear or gear ring is

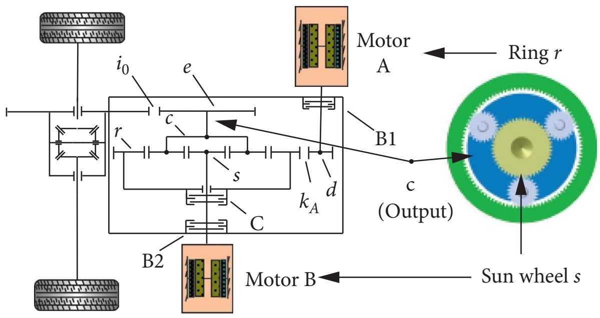

Figure 1: The diagrammatic sketch of dual-drive powertrain for pure electric vehicle.

subject to small resultant moment through zero-speed torque regulation and control. The motor regulation is fully utilized to realize the flexible mode switching, which is convenient for the brake and clutch disengagement or engagement and the reduction of the shift impact.

3. Parameter Matching Target and Scheme of Dual-Driving Powertrain System for Pure Electric Vehicles

The parameter design principles for the dual-driving powertrain system for pure electric vehicles are as follows: based on the parameters and the design performance indexes of the given vehicle model and under the premise of complying with the dynamic performance and driving mileage, the key parameters of the selected configuration and the performance indexes of the vehicle model studied in this paper are determined. See Table 1 for the vehicle performance index and vehicle parameters of the prototype vehicle.

After ensuring that the basic dynamic performance and economic performance (driving mileage) are met, this paper takes dynamic performance and economic performance as the dual objectives to carry out parameter optimization design, so as to select the key components of the power transmission system and determine the key characteristic parameters, including the drive system, the power battery system, and the power coupling system.

In this paper, the global optimization scheme is adopted, and the vehicle dynamic performance and energy consumption are taken as the dual optimization objectives. The basic dynamic performance and economic performance and the dynamic coupler characteristics are taken as the constraints. The optimization simulation platform integrating the vehicle numerical model and intelligent optimization algorithm is established. The key characteristic parameters of the power transmission system are used as optimization variables for comprehensive optimization. The key characteristic parameters of the power transmission system are optimized globally, and the optimization scheme is shown in Figure 2. The optimization scheme gives full play to the potential of the parameter matching of the power transmission system in the improvement of the vehicle performance to the greatest extent, as well as the potential of the new configuration of the dual-driving powertrain system for pure electric vehicles in energy saving [18, 19].

The impacts of various driving conditions on optimization effects are fully considered during the whole optimization process. If the optimization is based on a single driving condition, in general, the optimization results represent the optimal solution under that condition. However, if the vehicle is used for other working conditions, its adaptability may become worse and nonoptimal solution may appear. The multicondition parameter optimization method is used in this scheme, which has strong adaptability and fully considers the impacts of the efficiency characteristics of each component on the vehicle performance. In this research, intelligent optimization algorithm and continuous iterative calculation are used. Vehicle numerical model is used as the basis of performance evaluation. The optimization direction is guided, and the optimal parameter solution satisfying the requirements is searched through gradual iterations, thus achieving the global optimization design for the power transmission system parameters [20, 21].

4. Global Parameter Optimization of the Dual-Driving Powertrain System for Pure Electric Vehicles Based on Multiple Conditions

The parameters of the dual-driving powertrain system for pure electric vehicles are related to and affect each other. In this paper, the intelligent optimization algorithm is used to coordinate various impacts, and finally the most suitable global solution set is obtained. The parameter optimization design of dual-driving powertrain system for pure electric vehicles mainly includes the following processes: the determination of optimization objective function, the selection of optimization variables, the equation of constraint conditions, and the design of optimization algorithm.

4.1. Efficiency Analysis of Dual-Driving Powertrain System Optimization and Processing of the Objective Function. In this paper, the working characteristics of pure electric vehicles and the particularity of evaluation indexes are taken as research objectives; the vehicle dynamic performance and economic performance are considered. The acceleration time and driving mileage of the vehicle are taken as objective functions; the double-objective optimization function of dynamic performance and economic performance is established. The driving mileage of pure electric vehicles is improved to the largest extent on the premise of meeting the dynamic performance demand of the vehicle. In this paper, the acceleration time in 100 km is selected as the goal of dynamic performance optimization, and the driving mileage is selected as the goal of vehicle economic optimization [22].

4.1.1. Dynamic Performance Objective Function. The acceleration time in 100 km of the vehicle is shown as follows: fd1

Table 1: The performance indicators and parameter of pure electric vehicle.

	Item	Indicator	Unit
Maximum speed	Maximum speed	≥150	km/h
Acceleration	0~100 km/h acceleration time	≤15	s
Capability	0~50 km/h acceleration time	≤6	s
	Maximum gradient	≥35	%
Climbing ability	Maximum climbing speed	≥15	km/h
Endurance capacity	Pure electric driving range (60 km/h)	≥150	km
	Curb weight	1680	kg
	Windward area	2.275	m^2
Prototype vehicle parameters	Drag coefficient	0.3164	—
	Rotation mass conversion coefficient δ	1.04	—
	Wheel radius (dynamic)	0.308	m
	Rolling resistance coefficient	0.00995	—

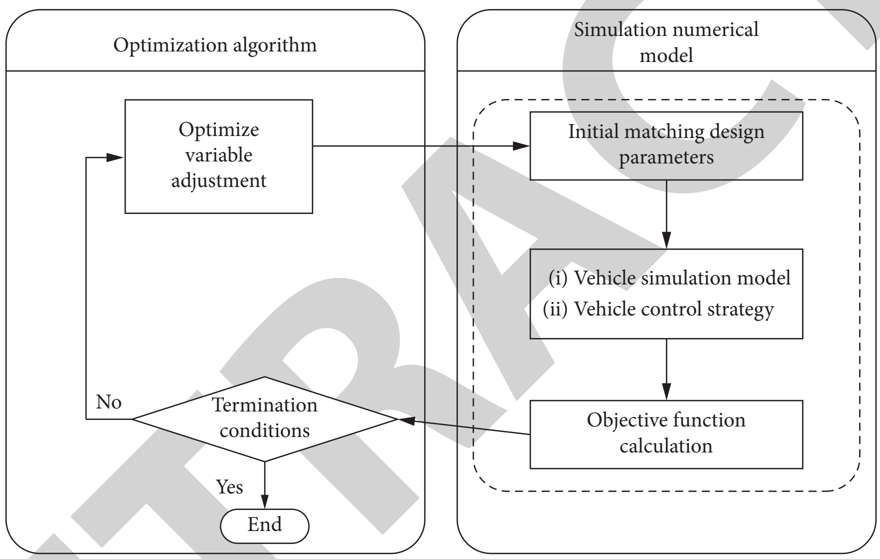

Figure 2: Schematic diagram of global optimization scheme.

$$t = \frac{1}{3.6}\int_0^{100} \frac{\delta m}{F_d - \left(\mathrm{mgf}_r + \left(C_D A v^2/21.15\right)\right)} \mathrm{d}v, \quad (1)$$

where F_d is the maximum driving force of the vehicle.

When the vehicle speed is lower than that corresponding to the rated speed, the motor will achieve constant output at the maximum torque; when the vehicle speed is higher than that corresponding to the rated speed, the motor can achieve constant operation at the maximum power; the output torque is a function of the speed. Therefore, the maximum driving force of the vehicle is a subsection function of the vehicle speed corresponding to the rated speed, as shown in the following equation:

$$F_d = \begin{cases} \dfrac{3600 P_{\mathrm{sys\,max}} \eta_T}{v_m}, & v \leq v_m, \\ \dfrac{3600 P_{\mathrm{sys\,max}} \eta_T}{v}, & v > v_m, \end{cases} \quad (2)$$

where V_m is the vehicle speed corresponding to the rated speed of the drive system motor, in km/h.

Therefore, the dynamic performance objective function is as follows:

$$f_1(x) = t = \frac{\delta m}{3.6}\left(\int_0^{v_m} \frac{\mathrm{d}v}{\left(3600 P_{\mathrm{sys\,max}} \eta_T / v_j\right) - \left(\mathrm{mgf}_r + \left(C_D A v^2/21.15\right)\right)} + \frac{1}{3.6}\int_{v_m}^{100} \frac{\mathrm{d}v}{\left(3600 P_{\mathrm{sys\,max}} \eta_T / v\right) - \left(\mathrm{mgf}_r + \left(C_D A v^2/21.15\right)\right)}\right), \quad (3)$$

where x is vector composed of optimization parameters.

4.1.2. Economic Performance Objective Function. The average driving mileage of the fully charged vehicle under multiple cycle conditions is taken as the economic performance evaluation index in the paper, and the driving mileage under each working condition is subject to weighted average handling. Through the analysis in [17] it can be found that the driving mileage of the vehicle under single-cycle condition can be expressed by

$$L_i = \frac{Q_b \cdot U_b \cdot \mathrm{DOD}}{1000 \cdot W_{\mathrm{cyclei}}} \cdot s_i, \quad i = 1, 2, \ldots, N, \tag{4}$$

where Q_b is capacity of power battery, U_b is total rated voltage, W_{cyclei} is the energy consumption of the vehicle when it operates under a certain cycle condition, S_i is driving mileage of vehicle under a certain cycle condition in km, and N is the number of cycle conditions.

Since the dynamic performance objective function $f_1(x)$ represents the minimum acceleration time, it is necessary to take the reciprocal of the weighted average driving mileage, thus ensuring that it is consistent with the optimization direction of $f_1(x)$. At the same time, the condition weighting coefficient ε_i is introduced, which can control the weight of each condition in the process of optimization calculation, $\sum \varepsilon_i = 1$. Therefore, the objective function of multicondition economic performance is as follows:

$$f_2(x) = \frac{1}{\overline{L}} = \frac{1}{\sum_{i=1}^{N} \varepsilon_i L_i}, \tag{5}$$

where $\overline{L}$ is average driving mileage under multiple working conditions and ε_i is working condition weighting coefficient.

4.1.3. Transformation of Objective Function. The multi-objective optimization problem is as follows:

$$\begin{cases} F(x) = \min\left[f_1(x), f_2(x), \ldots, f_i(x)\right], & x \in \Omega, \\ dl \le x \le ul, \\ A_j * x = Aeq_j, \\ B_k * x \le Beq_k. \end{cases} \tag{6}$$

In the process of solving multiobjective optimization problems, the subobjective functions may conflict with each other, and the performance improvement of one objective may reduce the performance of the other. Generally speaking, there is no absolute optimal solution which can achieve the optimization of all subobjective functions. The double-objective optimization (dynamic performance and economic performance) problem of pure electric vehicles is transformed into a single-objective optimization problem in this paper, which helps to obtain the solution and adjust the weight of each objective [23].

To transform the double-objective optimization problem of the vehicle into a single-objective optimization problem, in this paper, the above dynamic performance objective function $f_1(x)$ and the economic performance objective function $f_2(x)$ are weighted and summed up [24], and the new optimization objective function is as follows:

$$f(x) = \delta_1 f_1(x) + \delta_2 f_2(x), \tag{7}$$

where δ_1, δ_2 are weighting factor, which is greater than 0.

The weighing factor can be expressed by

$$\delta_j = \delta_{j1} \cdot \delta_{j2}, \quad j = 1, 2, \tag{8}$$

where δ_{j1} is the subobjective weighing factor, which is used to characterize the importance of subobjectives in the process of optimization design, which is greater than zero and $\delta_{11} + \delta_{21} = 1$; δ_{j2} is a correction weighing factor, which is used to adjust the impacts of the difference in magnitude between subobjectives on the optimization calculation, which may be gradually corrected in the iterative calculation. In general, the reciprocal of the design objective is taken as the initial value. Note that δ_j is a real number greater than zero.

4.2. Selection of Optimization Variables. The key parameters of the power system closely related to the vehicle performance are selected as optimization variables in this paper, namely, motor A rated power, motor A rated speed, motor B rated power, motor B rated speed, battery capacity, characteristic parameters of planetary gear, final ratio, and transmission ratio of motor A deceleration gear. The optimization variable vectors are as follows:

$$x = \left[P_{0A}, \omega_{0A}, P_{0B}, \omega_{0B}, Q_b, k, i_0, k_A\right]. \tag{9}$$

4.3. Constraint Condition. When setting the initial value of optimization variables and the boundary conditions of each variable, a variety of factors need to be considered comprehensively, such as the requirements of the basic performance of the vehicle, the cost of the vehicle, and the design experience. For the transmission system parameters, the principle that the components of the same system in mechanical design have similar service life shall be taken into account. In this paper, the boundary conditions of each variable are obtained after considering all influences, as shown in Table 2.

4.4. Optimization Algorithm. As the core of optimization calculation, optimization algorithm has a direct impact on the optimization convergence and the reliability of optimization results. Traditional optimization algorithms mainly include gradient method and steepest descent method. Such algorithms need accurate mathematical functions, as well as huge computing resources. As a computational model, genetic algorithm is based on the natural selection theory of Darwin's biological evolution theory and the biological evolution process of Mendel's genetic mechanism. It is composed of three parts (encoding and decoding, individual fitness evaluation, and genetic operation). The calculation model searches for the optimal solution complying with certain conditions by simulating the biological evolution process in nature, which is more suitable for the

Table 2: Optimal variable boundary condition.

Optimization variable	Initial value	Lower limit	Upper limit
Rated power of motor A (kW)	10	5	36
Rated speed of motor A (r/min)	2800	2500	4000
Rated power of motor B (kW)	26	5	36
Rated speed of motor B (r/min)	3200	2500	4000
Power battery capacity Q_b (Ah)	60	50	70
Characteristic parameters of planetary gear mechanism k	3	1.5	5
Final drive ratio i_0	2.32	1	7
Motor A reduction gear ratio k_A	6	1	8

optimization of iterative calculation [25, 26]. Therefore, genetic algorithm is used for the optimization design in this paper, and the optimization process is shown in Figure 3.

After repeated commissioning, the parameters for genetic algorithm are finally set as follows: the maximum evolution algebra is 80, the population size is 100, the elite number is 10, the proportion of cross offspring is 0.6, and the probability of mutation is 0.01. In addition, the rank sorting and decentralized cross function are adopted. Constrained adaptive mutation is used to achieve good convergence.

The whole optimization model includes the vehicle simulation model based on genetic algorithm toolbox in MATLAB/Simulink platform. Since the focuses of optimization calculation are the dynamic performance and economic performance, there is no need to consider the smoothness in the transient process of mode switching. Therefore, the control strategy based on logic threshold is used as the vehicle control strategy.

5. Global Parameter Optimization of the Dual-Drive Powertrain System for Pure Electric Vehicles Based on Multiple Conditions

In this paper, four typical conditions (NEDC, HWFET, WLTC, and CHCQ) are selected for the optimization calculation. NEDC and WLTC are usually used for regulatory testing, including low-speed and low-load condition and high-speed and high-load condition; HWFWT represents high-speed and high-load condition and uniform load condition; CHCQ condition can reflect local driving characteristics. In this paper, the simulation optimization process designed above is used for the global optimization calculation of the dual-drive powertrain system for pure electric vehicles. After nearly 50 rounds of iterations, the objective function tends to be constant and the change trend is shown in Figure 4. The optimal fitness optimization variable vectors are as follows:

$$x = [12.13, 2896, 13.86, 2479, 57.71, 2.823, 4.136, 1.482]. \tag{10}$$

In view of the actual situation of the parameter design of the power transmission system, in this paper, some parameters of the dual-drive powertrain system for pure electric vehicles are rounded up, and the parameters before and after optimization are compared in Table 3.

It is found after comparing the data before and after optimization that, compared with the parameters initially matched, the parameters after the global optimization through genetic algorithm have great changes in the following aspects: the power distribution, rated speed, and gear ratio of transmission system of the two motors. The motor power distribution is adjusted mainly based on the driving condition and the comprehensive efficiency of the driving system. If the weight of the economic target is changed, there will be some changes in the changing amplitude; the maximum speed and the gear ratio of transmission system are mainly based on the dynamic performance index (maximum vehicle speed, etc.). If the weight of dynamic performance target is changed, there will also be corresponding changes in the changing amplitude. There are no significant changes in the rated speed and the capacity of the power battery, only with a small range of changes, but the vehicle curb mass is reduced, which causes certain impacts on the dynamic performance and economic performance.

To verify whether the parameter optimization matching method of the dual-drive powertrain system for pure electric vehicles is effective, the parameters initially matched and parameters after optimization are, respectively, applied to the vehicle performance simulation platform for simulation, and its dynamic performance and economic performance are focuses of the simulation comparison. The changes in the parameters initially matched and parameters after optimization in the four typical conditions SOC are shown in Figure 5. It can be seen that the power battery SOC after optimization at the end of driving conditions is significantly higher than before, with a relatively slow change, indicating that the economic performance of parameters after optimization is significantly improved, and it can achieve more obvious energy-saving effect under high-speed conditions, indicating that the dual-drive powertrain system can improve the efficiency of driving system during high-speed cruise.

In this paper, parameters initially matched and parameters after optimization are calculated for dynamic performance, and Table 4 shows the comparison of simulation results. It can be seen from the table that the maximum vehicle speed has been increased by 9.06%, the acceleration time in 100 km has been shortened by 3.25%, and the maximum gradient has been increased by 6.33%.

In this paper, the parameters initially matched and parameters after optimization are applied to four typical conditions (NEDC, HWFET, WLTC, and CHCQ) to calculate the energy consumption and driving mileage of single cycle. The statistics and comparison of simulation results are

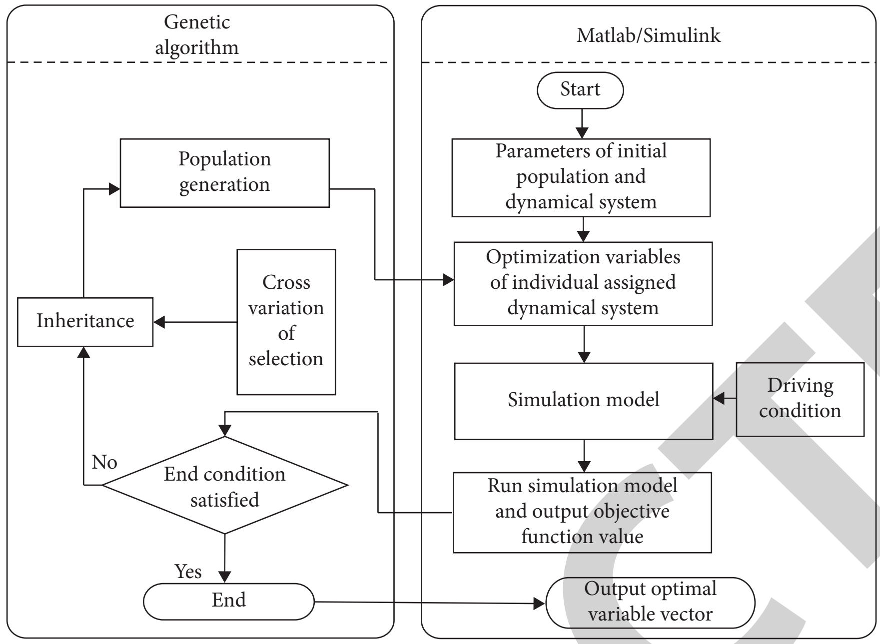

FIGURE 3: Genetic algorithms optimization flowchart.

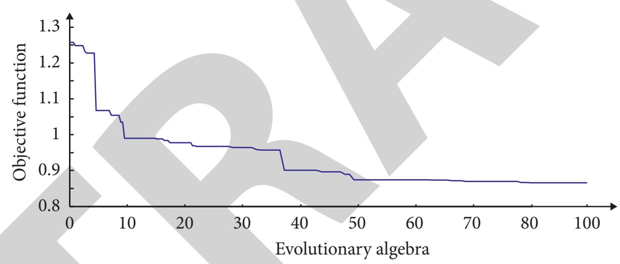

FIGURE 4: Change trend chart of objective function.

TABLE 3: Comparison of powertrain parameters after optimization.

Parts	Item	Before optimization	After optimization
Motor A	Rated/peak power (kW)	10/20	12/24
	Rated/maximum speed (r/min)	2800/8000	3000/8000
	Rated/maximum torque (N·m)	34/68	38.2/76.4
Motor B	Rated/peak power (kW)	26/52	24/48
	Rated/maximum speed (r/min)	3200/8000	2500/8000
	Rated/maximum torque (N·m)	77.5/155	91.68/183.36
Powertrain	Characteristic parameters of planetary gear mechanism k	3.8	2.823
	Motor A reduction gear ratio k_A	1.8	1.482
	Final drive ratio i_0	3.5	4.136
Power battery	Rated capacity (Ah)	60	58

shown in Table 5. It can be seen from the table that the HWFET condition shows the most obvious effect on the economic performance improvement, with an increased range of 9.2%, which once again shows that the efficiency improvement is the most obvious in the high-speed condition. At this moment, the dual-drive powertrain system is operating in the speed-coupling mode. The economic performance simulation results prove the correctness, feasibility, and obvious energy-saving potential of the energy-saving mechanism of the dual-drive powertrain system above.

6. Conclusion

The parameter matching of the power transmission system for pure electric vehicles is the premise and basis for the

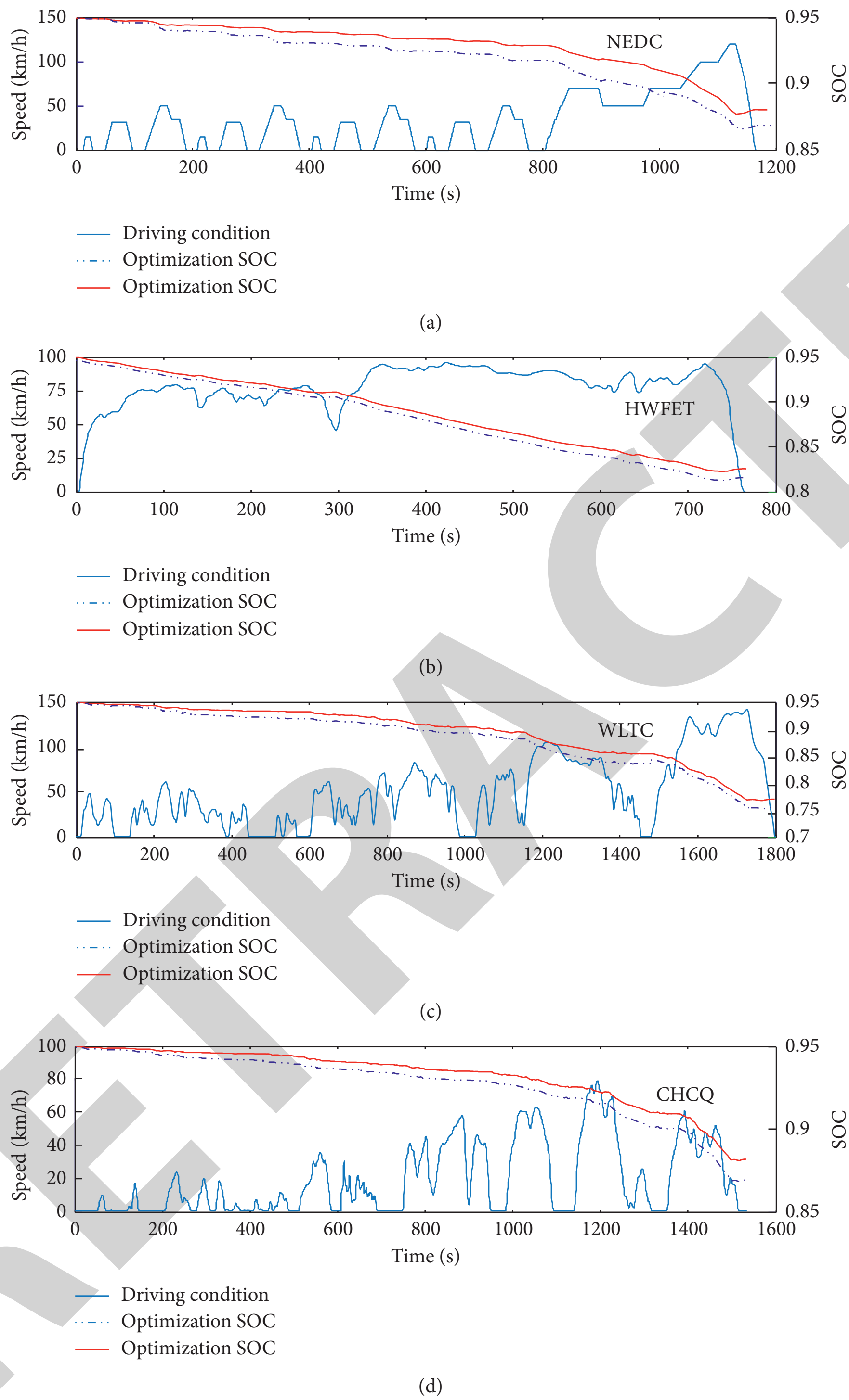

Figure 5: The SOC curve in different driving cycles before and after optimized parameters.

Table 4: Comparison of dynamic performance indicators after optimization.

Item	Preliminary match	After optimization	Changes %
Maximum speed (km/h)	155.6	169.7	9.06
100 km acceleration time (s)	14.77	14.29	−3.25
Maximum gradient at 15 km (%)	37.58	39.96	6.33

Table 5: Comparison of economic performance indicators after optimization.

Cycle condition	Item	Preliminary match	After optimization
NEDC	Total cycle energy consumption (kJ)	6002.22	5622.34
	Driving range (km)	120.76	128.39
HWFET	Total cycle energy consumption (kJ)	9033.26	8293
	Driving range (km)	112.6	122.96
WLTC	Total cycle energy consumption (kJ)	14838.4	13947.9
	Driving range (km)	104.8	111.2
CHCQ	Total cycle energy consumption (kJ)	5324.65	5066.98
	Driving range (km)	127.5	133.67

follow-up research on control methods. In this paper, with the focus on the parameter matching of the dual-drive powertrain system for pure electric vehicles, the numerical model of the dual-drive powertrain system is analyzed to establish the vehicle performance simulation platform. It can be found through the simulation results that the simulation platform can simulate the working process and performance of the vehicle in an accurate manner, which lays the foundation for the performance simulation of dual-drive powertrain system for pure electric vehicles and follow-up research on control methods, to improve the vehicle performance, a multiobjective optimization function (including dynamic performance and economic performance indexes) is established in this paper, and genetic algorithm is used for the optimization design of system parameters; then the parameters before and after optimization are calculated on the vehicle simulation platform. The calculation results show that both the vehicle dynamic performance and economic performance are improved in different degrees, proving that the optimization method is efficient and feasible.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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References

[1] M. Duoba, H. Ng, and R. Larsen, "In-situ mapping and analysis of the toyota prius HEV engine," in *Proceedings of the Future Transportation Technology Conference & Exposition*, SAE, Costa Mesa, CA, USA, August 2000.

[2] A. Kawahashi, "A new-generation hybrid electric vehicle and its implications on power electronics," in *Proceedings of the Annual Center for Power Electronics Systems Power Electronics Seminar*, pp. 15–20, Blacksburg, VA, USA, April 2004.

[3] K. Muta, M. Yamazaki, and J. Tokieda, "Development of new-generation hybrid system THS II—drastic improve-ment of power performance and fuel economy," in *Proceedings of the SAE 2004 World Congress & Exhibition*, SAE, Detroit, MI, USA, 2004.

[4] L. Chu, Y. Li, and Q. N. Wang, "Study on the parametric optimization for a par-allel hybrid electric vehicle power train," in *Proceedings of the Future Transportation Technology Conference & Exposition*, SAE, Costa Mesa, CA, USA, August 2000.

[5] Y. Dai, L. Song, and S. Cui, "Development of PMSM drives for hybrid electricar applications," *IEEE Transactions on Magnetics*, vol. 43, no. 1, pp. 434–437, 2007.

[6] J. Axsen and K. Kurani, *The Early US Market for PHEVs: Anticipating Consumer Awareness, Recharve Potential, Design Priorities and Energy Impacts*, University of California, Oakland, CA, USA, 2008.

[7] W. Zhao, *Parameter Matching Design of Powertrain for Battery Vehicle Based on Genetic Algorithm*, Jilin University, Changchun, China, 2017.

[8] W. Cheng, Y. Sun, G. Li, G. Jiang, and H. Liu, "Jointly network: a network based on CNN and RBM for gesture recognition," *Neural Computing and Applications*, vol. 31, no. 1, pp. 309–323, 2019.

[9] B. Li, Y. Sun, G. Li et al., "Gesture recognition based on modified adaptive orthogonal matching pursuit algorithm," *Cluster Computing*, vol. 22, no. 1, pp. 503–512, 2019.

[10] G. Li, D. Jiang, Y. Zhou, G. Jiang, J. Kong, and G. Manogaran, "Human lesion detection method based on image information and brain signal," *IEEE Access*, vol. 7, pp. 11533–11542, 2019.

[11] Y. He, G. Li, Y. Liao et al., "Gesture recognition based on an improved local sparse representation classification algorithm," *Cluster Computing*, vol. 22, no. 5, pp. 10935–10946, 2019.

[12] F. Zhou, *Research Powertrain Parameter Design and Vehicle Control Strategy for Pure Electric Vehicle*, Jilin University, Changchun, China, 2013.

[13] A. Sorniotti, S. Subramanyan, A. Turner, C. Cavallino, F. Viotto, and S. Bertolotto, "Selection of the optimal gearbox layout for an electric vehicle," *SAE International Journal of Engines*, vol. 4, no. 1, pp. 1267–1280, 2011.

[14] Y. Zhu, Z. Wang, G. Han, G. Zhao, and N. Yang, "Orthogonal optimal design for drive system parameter of electric vehicle based on vehicle driving cycle," *Journal of Central South University*, vol. 44, no. 2, pp. 216–221, 2013.

[15] J. Kowal, J. B. Gerschler, C. Schper et al., "Efficient battery models for the design of EV drive trains," in *Proceedings of the Power Electronics and Motion Control Conference*, IEEE, Ohrid, Macedonia, pp. S11–S38, September 2010.

[16] M. Spichartz, A. Steimel, and V. Staudt, "Stator-flux-oriented control with high torque dynamics in the whole speed range for electric vehicles," in *Proceedings of the Emobility Electrical Power Train*, pp. 1–6, IEEE, Leipzig, Germany, November 2010.

[17] Y. Wang and J. Deng, "Control strategy of dual-drive powertrain system of pure electric vehicle based on real-time optimization," *International Journal of Performability Engineering*, vol. 15, no. 12, pp. 3108–3116, 2019.

[18] D. Jiang, G. Li, Y. Sun, J. Kong, and B. Tao, "Gesture recognition based on skeletonization algorithm and CNN with ASL database," *Multimedia Tools and Applications*, vol. 78, no. 21, pp. 29953–29970, 2019.

[19] G. Li, H. Tang, Y. Sun et al., "Hand gesture recognition based on convolution neural network," *Cluster Computing*, vol. 22, no. 2, pp. 2719–2729, 2019.

[20] G. Li, H. Wu, G. Jiang, S. Xu, and H. Liu, "Dynamic gesture recognition in the internet of things," *IEEE Access*, vol. 7, pp. 23713–23724, 2019.

[21] J. Qi, G. Jiang, G. Li, Y. Sun, and B. Tao, "Intelligent human-computer interaction based on surface EMG gesture recognition," *IEEE Access*, vol. 7, pp. 61378–61387, 2019.

[22] W. Liu and G. Yin, *Hybrid Vehicle System Modeling and Control*, China Machine Press, Beijing, China, 2015.

[23] S. Soylu, *Electric Vehicles—Modelling and Simulations*, IntechOpen, London, UK, 2011.

[24] L. Guzzella and A. Sciarretta, *Vehicle Drive System Modeling and optimization*, China Machine Press, Beijing, China, 2015.

[25] W. Zhao, *Parameter Matching Design of Pure Electric Vehicle Powertrain Based on Genetic Algorithm*, Jilin University, Changchun, China, 2017.

[26] F. Zhou, *Research on Powertrain Parameter Matching and Vehicle Control Strategy of Pure Electric Vehicle*, Jilin University, Changchun, China, 2013.