Research on Key Technologies of Computer Simulation for Vehicle Engineering Engine

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Abstract. The paper analyses the importance of simulation technology for the research and development of hybrid engines in vehicle engineering, and introduces the current development status and key technologies of hybrid engine simulation technology, and puts forward the focus of future research. Simultaneously, taking the hybrid electric vehicle as a case, through the analysis of the drive structure and work requirements, to optimize the power performance and fuel economy of the vehicle, the electric assist control strategy for the hybrid power system is proposed. The control logic formulates the driving conditions. A related control model was established, and the control strategy was simulated on the Advisor software platform. The simulation results show that the proposed electric-assisted control strategy is entirely suitable for hybrid electric vehicles. Compared with traditional vehicles, the power performance and fuel economy of the whole vehicle are further improved.

Keywords: Vehicle engineering, engine, computer simulation technology, hybrid electric vehicle, electric auxiliary control strategy.

1. Introduction

With the continuous growth of automobile usage, global carbon dioxide emissions and energy crisis issues are also increasing day by day, and the international community's attention is also increasing. Hybrid electric vehicles are less dependent on fossil fuels and have high power performance. Therefore, the development of hybrid electric vehicles is a feasible and effective solution to environmental and energy problems. In the 1960s, the rapid development of computer industry technology and its application in the aviation field enabled hybrid engine simulation technology development. Hybrid engine simulation technology is a subject based on system science, computer science, fluid mechanics, thermodynamics, control theory, network theory, and other disciplines [1]. The hybrid engine is the central processing object, and mathematical models and digital computers are used. Comprehensive technology as the primary research tool. The purpose of the simulation is to obtain the essential characteristics of the model under different working conditions (start, acceleration, cruise, slow car, windmill, etc.) through the observation and statistics of the engine steady-state and dynamic simulation model operation process, and to obtain the essential characteristics of the engine under the real working state. The performance is evaluated and predicted to realize the engine structure's improvement and optimization and control law design.

1.1. The critical technology of hybrid engine simulation

Figure 1 is a schematic diagram of the parallel hybrid electric vehicle structure studied in this article. The electric motor is arranged between the engine and the transmission, and the power output end of the engine's crankshaft is connected with the electric motor through an electronic control clutch. The motor not only functions as a starter but can also work in the motor state to drive the car or work in the generator state to recover braking energy [2]. The electronically controlled clutch can realize the vehicle's pure electric operation or the recovery of regenerative braking energy when it is disconnected. When combined, it can realize an electric auxiliary drive to adjust the motor's output power and play the role of "reducing peaks and filling valleys" so that the engine can keep Work in a high-efficiency zone.

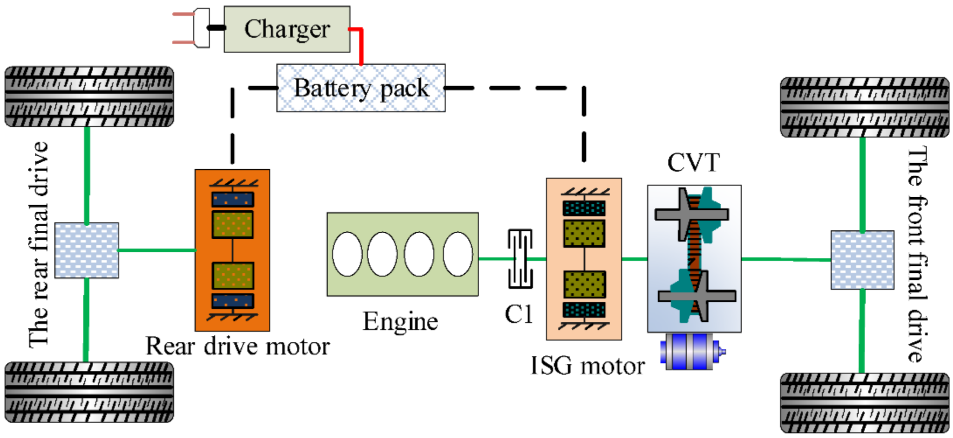

Figure 1. Schematic diagram of a hybrid vehicle structure

1.2. Simulation of the start-up state

When the engine is started, the airflow rate and the rotor speed are both low. At this time, both the compressor and the turbine can exhibit a complicated compression, expansion, and friction process. Generally, engine simulation requires compressor and turbine characteristic maps, and characteristic lines below the slow speed cannot be obtained by experiments. These all bring difficulties to the simulation of the starting state. At present, there are two leading solutions: one is to consider that the characteristic lines of different engines below the slow car are the same, and then use the characteristic line below the slow car of an impressive engine to perform general calculations; the other is based on the test data of the existing engine, Using Nechaev Petrov's method to estimate the characteristic line below the slow train [3]. When using these two methods to calculate when the compressor pressure ratio is less than 1, the compressor temperature rise ratio should be used instead of the efficiency to calculate because the compressor efficiency in this section should be negative by definition, and it is not continuous during the state change.

1.2.1. Starting conditions. When the car starts, the motor will drag the engine to the defined minimum ignition speed N_{start} in a short period (generally no more than 0.4ms) and then inject fuel to ignite so that the engine directly enters the economic zone for operation. Due to the engine's high fuel injection speed, the amount of fuel required for starting is much smaller than that of a traditional engine. This can significantly reduce fuel consumption and incomplete combustion pollutant emissions under starting conditions. In the process of car driving, if the engine speed is lower than N_{start} due to deceleration or neutral stop, the engine immediately stops fuel injection without idling, eliminating high energy consumption and high emissions under idling conditions. The logical relationship of the above engine start is:

$$N \succ N_{start} \tag{1}$$

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In the formula, N is the engine speed. If the formula's logic relationship is satisfied, the engine will ignite fuel injection, otherwise, stop fuel injection and shut down the engine.

1.2.2. Driving conditions. When the car is driven at low speed or low load, if the driving resistance is small, the engine load rate will be reduced, the operating point will exceed the economic zone, the engine will be turned off, and the car will be driven by the motor alone. When $T_{req} \prec T_{emin}$:

$$\begin{aligned} T_e &= 0 \\ T_{isg} &= T_{req} \end{aligned} \tag{2}$$

In the formula, T_e is the engine torque, T is the motor torque, and T_{req} is the driving demand torque. At this time, the motor torque is a positive value, and the motor is working in the motor state and outputs torque. When a car is cruising under a medium load, the engine is started. At this time, the engine's operating point is in the economic zone, and fuel consumption is low. The driving torque to overcome all the driving resistance of the car is provided by the engine.

1.2.3. Deceleration and braking conditions. When the car is decelerating, the control system receives the braking signal and starts braking. The engine immediately stops fuel injection, and the motor switches to generator mode, which generates braking resistance and maximizes the recovery of braking energy to charge the battery. which is

$$\begin{aligned} T_e &= 0 \\ T_{isg} &= T_{req} \end{aligned} \tag{3}$$

At this time, the motor torque T is harmful, indicating that the motor is working in the generator state to absorb braking energy charging, and the road demand torque T_{req} is also negative, indicating that the car is braking.

1.3. Solving differential equations
When a model based on component characteristics is used for simulation, the solution of differential equations requires not only sufficient accuracy but also good convergence, which usually conflicts with the real-time requirements of simulation [4]. Existing software usually adopts the first-order precision time difference format to simplify the differential equations into nonlinear equations and then use the Newton-Rapson method to solve them.

2. Vehicle engineering engine model simulation

2.1. Objective function
Since power and economy are the two most important indicators of a car, this paper uses the power evaluation index and the economic evaluation index as the model's objective function. In this paper, the acceleration time of continuous shifting in situ as the dynamic objective function is expressed as follows:

$$t=\int_{0}^{v_{1max}}\frac{1}{\alpha_1}\circ dv+\int_{v_{1max}}^{v_{2max}}\frac{1}{\alpha_2}\circ dv+\int_{v_{2max}}^{v_{3max}}\frac{1}{\alpha_3}\circ dv+\int_{v_{3max}}^{v_{4max}}\frac{1}{\alpha_4}\circ dv+\int_{v_{4max}}^{v_{5max}}\frac{1}{\alpha_5}\circ dv$$
$$\alpha_i=\frac{1}{\delta^\circ m}\left[\frac{T_{tq}i_j i_0\eta T}{r}-G_\circ f-\frac{G_D\circ A}{21.15}v^2\right] \tag{4}$$

α_i is the acceleration of the i gear. Among them: T_{tq} is the engine torque, obtained by curve fitting; i_g is the transmission ratio of each gear; ηT is the mechanical efficiency of the drive train, r is the rolling radius of the wheel; f is the rolling resistance coefficient; the CD is the air resistance coefficient; A Is the windward area of the car; δ is the conversion factor for the rotation mass of the car [5]. Taking the fuel consumption Q_s (unit: L/100km) per 100 kilometers of the simulated test cycle as the economic objective function, it is expressed as follows:

$$Q_s=\frac{\Sigma Q}{s}\times 100 \tag{5}$$

In the formula, ΣQ is the sum of fuel consumption in six working conditions (ml); s is the driving distance of the entire cycle (m).

2.2. Constraints

This model's constraints are mainly the gear ratio interval requirements of the transmission and the power requirements of the automobile-related to the transmission ratio [6]. The transmission ratio of each gear of the automobile drive system is generally distributed in a proportional series so that it is not only convenient to shift gears but also can make full use of the power of the engine but considering the utilization of higher gears and driving time and mileage are much more than low gears. Therefore, the proportional series's distribution plan is modified so that as the gear position increases, the transmission ratio of the adjacent two gears gradually decreases.

$$\begin{aligned}
&x_1/x_2\le 1.15\sqrt[4]{x_1}\\
&x_2/x_3-x_1/x_2\le 0\\
&x_3/x_4-x_2/x_3\le 0\\
&x_4/x_5-x_3/x_4\le 0\\
&0.9\sqrt[4]{x_1}-x_4/x_5\le 0
\end{aligned} \tag{6}$$

The design variable x_i is the transmission ratio of each gear. For example, x_0 is the primary reduction ratio i_0 x_1 and the first gear transmission ratio i_1. Considering that the car has adequate power performance, that is, it should have enough top-end power factor and first-gear maximum power factor, and at the same time, it needs to meet the adhesion conditions at the first-gear maximum driving force. The constraint conditions are described as follows:

$$\frac{1}{G}\left(\frac{Temx0\eta T}{r}-\frac{G_D\circ A}{21.15}v_a^{\,2}\right)\ge D_{0max} \tag{7}$$

2.3. Optimization method

This is a multi-objective optimization problem. The constraint method is selected to solve this model. According to the constraint method's characteristics and the model, the economic objective function is the primary objective function. The dynamic objective function is used as the secondary objective function so that this multi-objective optimization problem can be transformed into two single-objective constrained optimization problems. The optimization design's interior point method in the penalty function method is used to solve the optimization model. A calculation program (the program is omitted) is written using vb language, and a set of optimized simulation design software is established on this basis [7]. The software includes the following modules: Parameter input module: provides basic parameters required for simulation and optimization calculation; curve simulation module: realizes computer simulation of engine universal characteristics and torque curves, as shown in Figure 2; design calculation module: construction model, carry out optimization calculation; result post-processing module: Carry out simulation calculation on the leading performance indicators of the car.

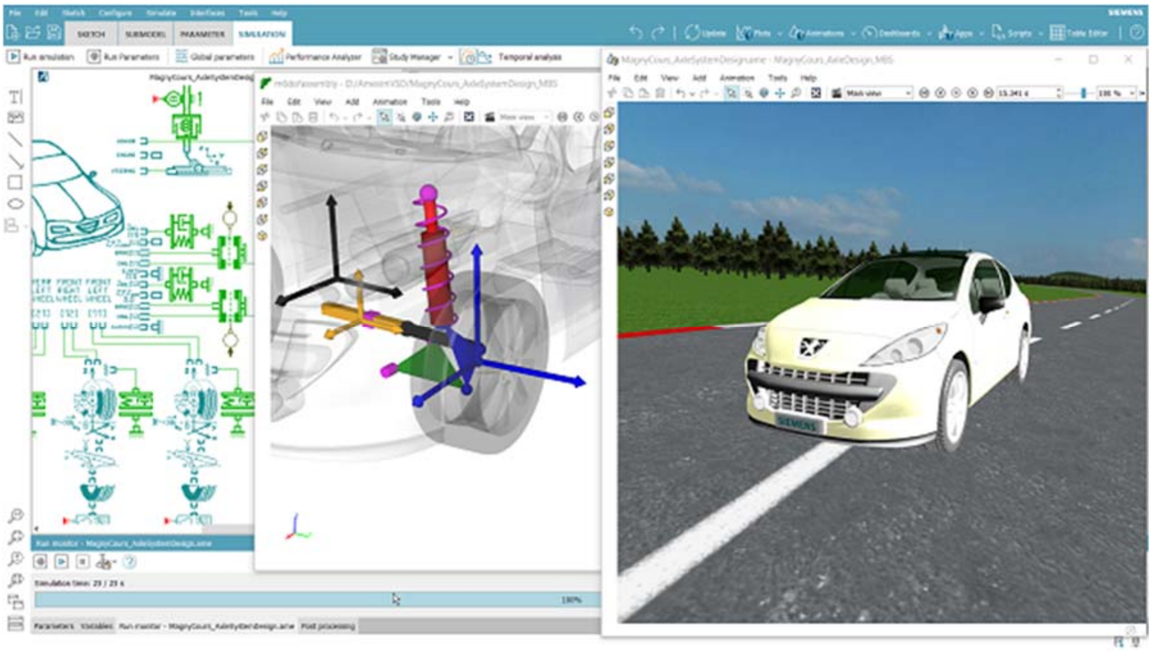

Figure 2. Optimization simulation design software for an automobile transmission system

3. Analysis of simulation results

This article focuses on the analysis of the influence of the electric-assisted control strategy's parameters on the efficiency of the motor and engine, the overall efficiency of the system, and the overall fuel consumption. The model for simulation analysis is the default parallel hybrid electric vehicle PARALLEL-defaults-in in ADVISOR. The working condition used in the simulation is the UDDS urban cycle working condition, and the simulation results are shown in Figure 3 and Figure 4.

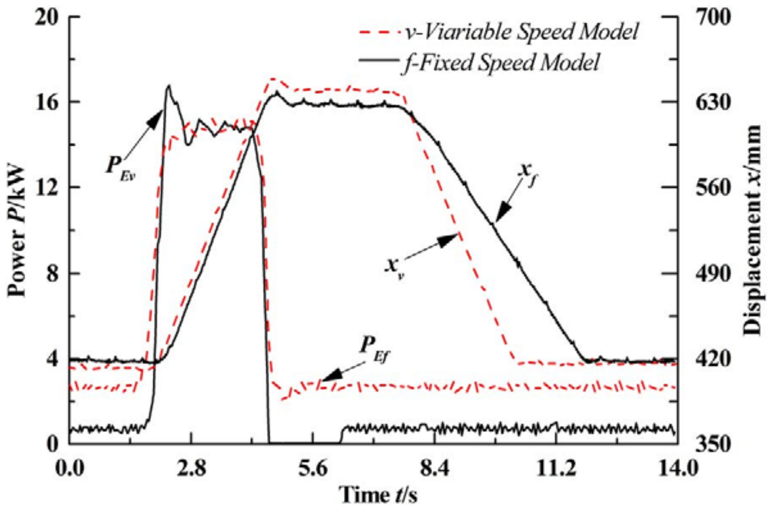

Figure 3. Motor efficiency diagram before adjustment of control strategy parameters

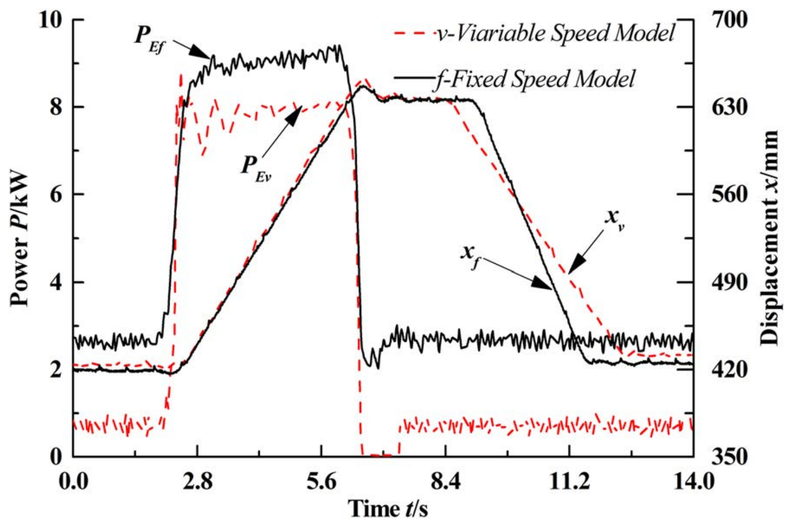

Figure 4. Motor efficiency diagram after adjustment of control strategy parameters

As shown in Figure 3 and Figure 4, the working efficiency of the motor is mainly distributed in the interval [0, 0.7] before the adjustment of the control strategy parameters, and the working efficiency of the motor is mainly distributed in the interval [0.1, 0.8] after the adjustment of the control strategy parameters. In the meantime, the working efficiency of the motor has been improved compared to before.

4. Conclusion

According to the different types of computers used in the simulation process, the automotive engineering hybrid engine's computer simulation can be divided into analogy machine simulation, digital machine simulation, and analogy-digital hybrid machine simulation. With the rapid development and widespread popularity of digital computers, especially the research and development of parallel processors and parallel processing technologies, digital computer simulation has now become the mainstream form. The comparison results prove that the electric-assisted control strategy based on the hybrid power system proposed in this paper has apparent effects in improving the system's power performance and fuel economy. It is entirely suitable for hybrid electric vehicles' control requirements, and the control logic is simple. It requires a high cost, is economical, reliable, and practical.

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