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MODELING AND SIMULATION OF HYBRID ELECTRIC VEHICLE BASED ON MATLAB/SIMULINK

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ABSTRACT

Computer simulation is an essential means to study the energy management strategy of hybrid electric vehicles. Through computer simulation technology, it can help to reduce unnecessary prototype manufacturing and real vehicle experiments, shorten development time, and save development costs. This paper is written to guide designers to use the "Hybrid Electric Vehicle Simulation System." It is hoped that this article will enable them to reduce unnecessary vehicle maintenance manufacturing and real vehicle experiments. This paper introduces the driver model, energy management strategy model, power source model, transmission system model, and dynamic model of the hybrid electric vehicle. It is convenient for users to match parameters, analyze performance and design energy management strategy for driving simulation hybrid electric vehicle.

KEYWORDS: Hybrid Electric Vehicle; Computer Simulation; Energy Management Strategy.

1. INTRODUCTION

With the awakening of social, environmental awareness, and high energy prices, people's requirements for vehicles are no longer just high power, high trafficability, and high comfort. On the contrary, more and more people pay more attention to the environmental protection and fuel-saving performance of vehicles when choosing vehicles[1]. So far, there are three primary technical schemes to meet the requirements of vehicle environmental protection and energy-saving, namely hybrid electric vehicle, pure electric vehicle, and fuel cell vehicle. Due to the limitation of the current technology level, there is a big gap between the pure electric vehicle and traditional vehicle. Fuel cell vehicle only exists in the laboratory. The hybrid electric vehicle is a better technology route at present[2,3,4].Multi-energy powertrain control, motor drive system, power battery, and management system are three critical technologies for the development of hybrid electric vehicles. In order to meet the power requirement of a parallel hybrid electric vehicle. Verify the feasibility and real-time of energy management strategy.

2. RESEARCH ON DRIVER MODEL

In the parallel hybrid electric vehicles, the driver model is essentially to compare the actual speed with the expected rate under cyclic conditions.

The driver model is used to obtain acceleration pedal signal and to brakethe pedal signal, and to make the actual speed as close as possible to the expected rate.

The driver model established in this paper, as shown in the figure1:

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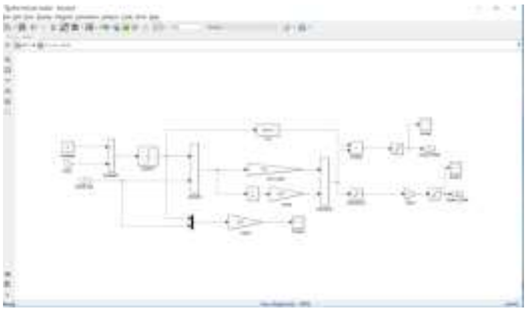

Fig1. Driver Model

In the figure above: Actual_spd is the Actual Speed; Clock is the Driver reaction delay; Accel_Pedal is the Accelerated pedal output signal, and Brake_Pedal is the Braked pedal output signal.

3. RESEARCH ON ENGINE MODEL

Modeling methods of engine models can be divided into theoretical and experimental models. The engine model used in the simulation model of the hybrid electric vehicle generally adopts the method of experimental modeling[5]. Through the engine performance test, the fuel consumption and emission data of the engine at different speeds and torques are obtained. The engine model is established by looking up tables and interpolating methods. As shown in Figure 2 below:

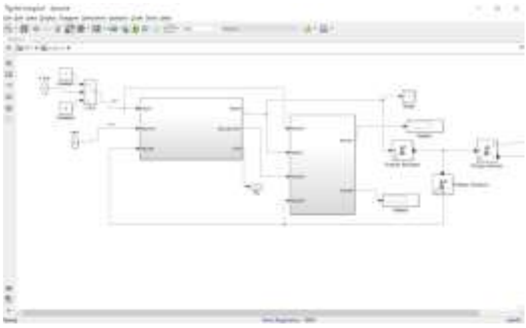

Fig2. Engine Model

The input of engine model is vehicle control signal CMD, and the output torque of instantaneous vehicle speed acts together with the output torque of motor after transmission and is fed back to the vehicle control unit through the torque sensor.

4. RESEARCH ON MOTOR MODEL

For parallel hybrid electric vehicles, only the input and output of the motor module need to be paid attention to, and the complex internal electromagnetic relationship need not be paid attention. Therefore, we can meet the requirements by looking up the table model.

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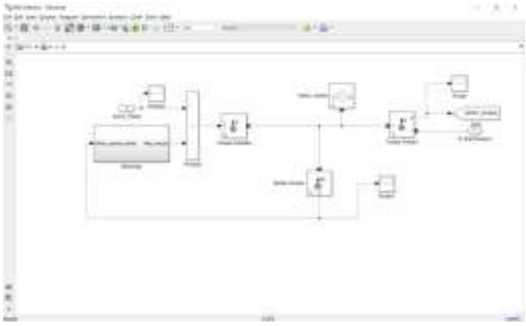

Fig3.Motor Model

5. RESRARCH ON TRANMISSION MODEL

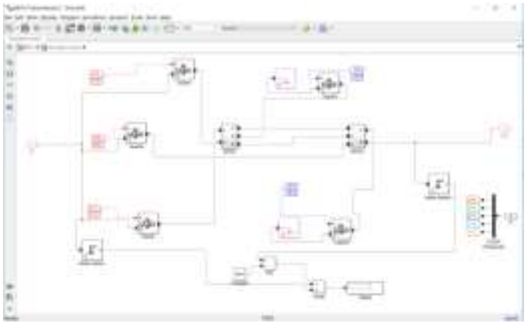

Fig4.Transmission Model

After the instructions of the accelerator pedal and brake pedal reach motor and engine, the output torque of engine and motor is selected according to different logic threshold energy feedback strategies. There are many methods of logic threshold energy feedback strategy. Here, the equivalent fuel method is adopted.

6. RESEARCH ON VEHICLE CONTROL MODEL

Vehicle control model is based on the cycle speed and fuel efficiency to determine different generator and engine allocation modes. Based on the optimal engine working curve energy management strategy and the optimized energy management strategy, the simulation model is shown in figure 5.

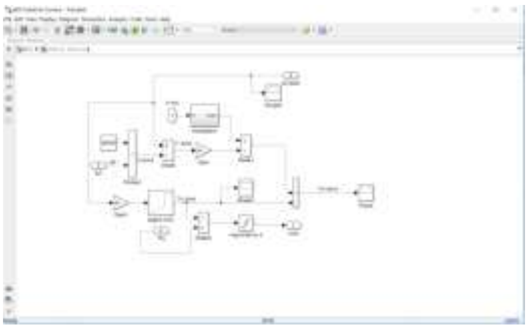

Fig5.Vehicle Control Model

RESEARCH ON CLUTCH HYDRAULICS MODEL

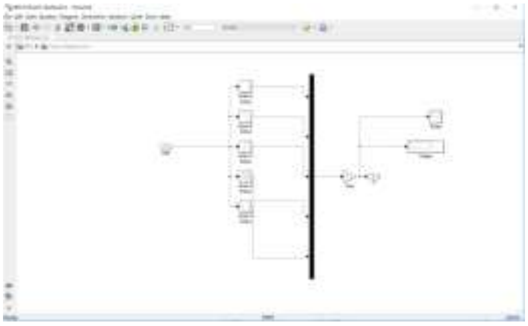

Fig6.Clutch Hydraulics Model

The transmission system of hybrid electric vehicle in this paper consists of three parts: transmission, main reducer, and power coupler. The modeling of the three parts has some similarities, that is, the input is the torque of the former stage and the speed of the latter stage, and the output is the torque and speed of the latter stage. The influence of transmission ratio and efficiency is considered in the middle.

In this paper, the transmission shifting strategy chooses the speed as the only parameter. When the detected speed is lower than the set speed, the output torque of the transmitter rises, and When the speed is lower than the set, the transmission reduces, without considering the influence of engine speed, throttle opening, and other parameters.

7. RESEARCH ON DYNAMIC MODEL

The main task of the dynamic model is to input the torque of the transmission system into the drive system and return the data of vehicle speed and wheel speed. It mainly includes two parts, braking model and driving dynamic model.

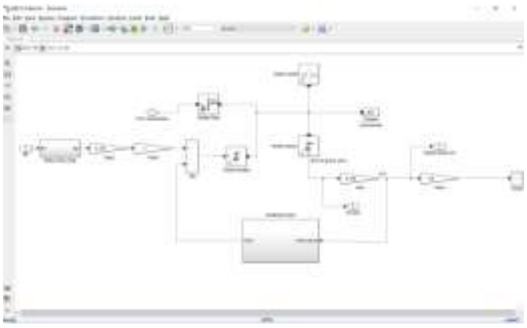

Fig7.Dynamic Model

- Braking model: In the whole vehicle model of the parallel hybrid electric vehicle, the main function of the braking model is to calculate the braking force provided by mechanical brake device according to the total braking moment and the braking moment provided by the motor[6]. The input of the braking model is the total braking moment required by the vehicle and the braking moment provided by the motor, and the output is the mechanical braking force. Since this paper only considers the longitudinal dynamics of the vehicle and does not need to consider the distribution of braking force between front and rear wheels, the mechanical braking force of the braking model can be calculated by formula 1.

$$\text{Brake\_force\_map} = \frac{T_{brake} - T_{brake\_m} i_{tc}}{r} \times i_0 \qquad (1)$$

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In the formula:

Brake_force_map:Braking force provided by mechanical brake device, N;
T_{Brake}:Total Braking Torque for Vehicle, N.M;
T_{brake_m}:Braking Torque Provided by Motor, N.M;
i_t:Main deceleration ratio;
r:Wheel rolling radius, M;

- Driving Dynamics Model: In this paper, the driving dynamics model of a parallel hybrid electric vehicle is established based on the vehicle driving equation. The input of the model is the driving moment and mechanical braking force, and the output is vehicle speed and wheel speed.

Vehicle acceleration can be calculated by the formula (2):

$$\frac{vehicle\ speed}{dt} = \frac{\frac{Torque\ Actuator}{r} - \text{Brake}_{\text{force}_{\text{map}}} - \text{mgcos}\alpha - \text{mgfsin}\alpha}{\delta_m} \quad (2)$$

8. RESEARCH ON VEHICLE SIMULATION MODEL

After establishing the models of each component of the parallel hybrid electric vehicle, the whole vehicle simulation model can be established by linking the models of each component according to the structure and logic relationship, as shown in figure 8.

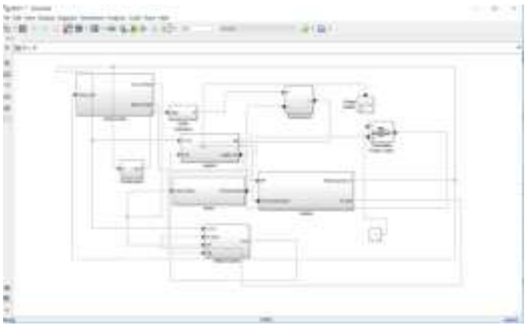

Fig8.Vehicle Simulink Model

9. RESEARCH ON SIMULATION FLOW OF EACH MODULE

After the system simulation begins, the parameters such as ideal vehicle speed u I, ideal torque Ti and ideal acceleration time ti should be preset. After the simulation starts, according to the parameters such as simulation measured vehicle speed u, simulation engine torque Tm, simulation motor torque Te and simulation battery management system SOC, the energy management strategy will choose the driving mode to give the engine and electric motor[7]. The machine sends torque instructions, and then outputs vehicle speed, motor torque, and engine torque through transmission system model and vehicle dynamics model simulation, calculates 100 km acceleration time, outputs acceleration curve, and ends the simulation[8]. Among them, the equivalent fuel consumption method is used to calculate the SOC parameters, that is, the equivalent energy consumption of the engine and the battery pack at each time is calculated, and then the consumption to meet the driver's needs at that time is calculated. The whole simulation process is shown in the following figure9:

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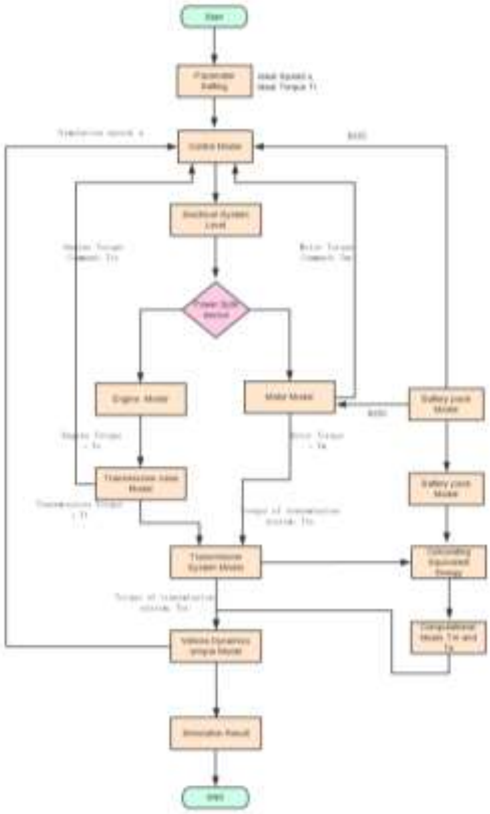

Fig9. Simulink Process Flow

10. ANALYSIS OF SIMULATION RESULTS

The simulation results of the vehicle control module are shown in Figure10. The blue curve is the required motor torque, and the Yellow curve is the pedal output signal. The graph shows that when there is a demand for motor torque between 0 and 100 seconds, the pedal signal is positive. The same situation occurs in the range of 150 to 200 seconds. The vehicle control module runs normally.

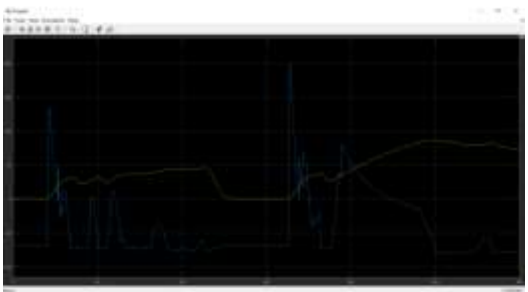

Fig10. Simulation of Vehicle Control Module

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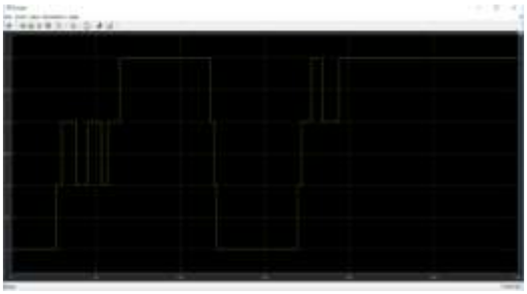

Fig11. Simulation of Change Gears Model

Fig12. Simulation of ClutchHydraulics Model

From the comparison of the curves in Figure. 10 and Figure. 11, it can be seen that when the pedal signal needs the maximum forward growth, the gear shifts rapidly from one gear to three gears, and when motor torque continues to be needed, the gear shifts from three gears to four gears. The engine and motor are adjusted by shifting, and the shifting is correct. The comparison of the curves in Figure. 11 and Figure. 12 shows that the gear shifting is correct. The adjustment of the clutch also meets the requirements.

The corresponding curves of Figure. 13, Figure. 14 and Figure. Fifteen show the acceleration mode of the hybrid electric vehicle. When starting, the engine cuts off the first gear to provide the starting torque. In the acceleration stage, the engine and the motor simultaneously output the torque. In uniform speed stage, the motor stops the output torque, and only the engine provides the torque. This control mode originates from, etc. The simulation results are correct by the effective fuel method.

Fig13. Simulation of Engine Model

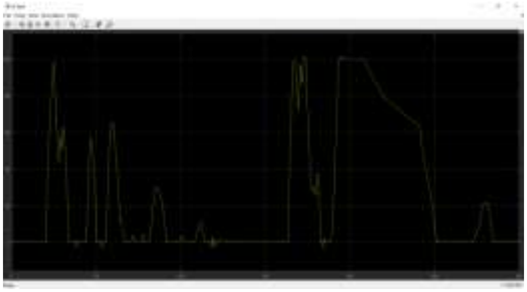

Fig14. Simulation of Motor Model

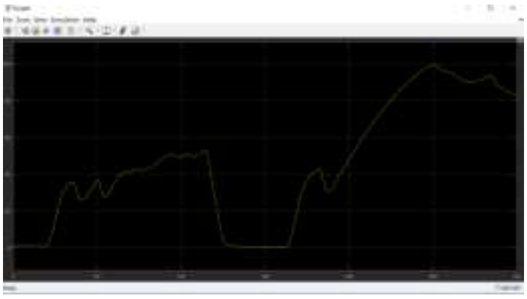

Fig15. Simulation of Vehicle Model

11. CONCLUSION

In this paper, a PHEV vehicle simulation model is established under MATLAB/SIMULINK environment by using the method of experimental modeling and theoretical modeling, referring to relevant literature. It consists of the driver model, engine model, motor model, transmission system model, vehicle control model, and energy feedback model. The relationship and significance of each module curve verify the feasibility of the energy management strategy.

12. DISCUSSION

This paper determines the structure of the parallel hybrid electric vehicle, establishes the PHEV dynamic test model, verifies the rationality of parameter design, but there are still some problems:

- In this paper, the forward simulation model of the whole vehicle is established, but the off-line simulation of the system has not been carried out under the standard driving cycle.
- Although the instantaneous optimization algorithm improves the overall efficiency of the whole system, it reduces the working efficiency of the engine.
- Instantaneous optimization algorithm has little effect on fuel economy.
- Logical Threshold Strategy in Energy Feedback Strategy cannot be optimized.

13. ACKNOWLEDGEMENT

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