Research on the Matching of Parallel Hybrid Vehicle Power System Based on Fuzzy Control

Zhiyong WANG
Binzhou University, China

ABSTRACT :*In order to improve the fuel economy of parallel hybrid vehicle and reduce the exhaust emission, hybrid power system is taken as the object of research, the scheme analysis and matching design of hybrid power system are carried out, the fuzzy logic control strategy of hybrid power system is proposed, and the dynamic system of hybrid vehicle with fuzzy control is modeled and simulated. Finally, in UDDS and 1015 cycle conditions, the performance of hybrid power system under the strategy of electro-assisted control and fuzzy logic control is analyzed. The results show that the hybrid system with fuzzy logic control have better performance, which provides a reference to further study on the optimization and control of hybrid vehicle power system.*

KEYWORDS -*parallel hybrid electric powertrain; matching of power system; fuzzy control*

I. INTRODUCTION

As increasing strict requirements on automobile fuel consumption and emission standards in various countries, decreasing automobile's dependence on traditional fossil fuels and reducing environmental pollution have become major problems of the automobile industry for a long time [1]. Due to the limitation of current technical level, especially the limitation of storage battery and fuel cell technology, endurance capability of electric vehicle are still insufficient, and all-electric cars cannot completely replace internal combustion engines cars, whose promotion and use have been greatly restricted. While hybrid electric vehicles not only have the advantages of strong endurance and quick refueling of traditional internal combustion engines, but also have the advantages of high efficiency of pure electric vehicles and low emission pollution. Therefore, hybrid electric vehicles have become a transitional scheme for traditional internal to solve energy and environmental problems [2]. At present, national governments have promulgated corresponding policies and regulations one after another to encourage and support the development of hybrid vehicles. However, how to achieve good cooperation between the engine and motor and improve engine working efficiency to obtain lower fuel consumption and emission are still an important research direction of hybrid vehicle design.

II. SCHEME MATCHING

2.1 Engine parameter selection

The hybrid vehicle studied in this paper take a certain type of car as the basic vehicle model, and the basic parameters. According to the power demand of vehicle at constant speed, the maximum output power of hybrid vehicle engine is,

$$p_{\max 1} = \frac{u}{3600\eta_t}\left(mgf + \frac{C_D A u_{\max}^2}{21.15}\right) \quad (1)$$

1. In the formula, p_{max1} is maximum total power; η_t is efficiency of automotive power transmission system, g is the gravitational acceleration, f is the rolling resistance coefficient; C_D is drag coefficient; A is frontal area; u_{max} is maximum speed, u is rating vehicle speed; u_{avg} is the average speed that vehicles often use, in urban driving conditions, the referencing of u is $u_{avg} \le u \le u_{max}$, according to the design requirement, the minimum power of the engine is calculated as 65 kw (considering the power of battery charging).

2.2. Motor parameter selection

On a good horizontal road surface, the acceleration of the vehicle is in equation,

$$\frac{d_v}{d_t} = \frac{F_t - F_w - F_f}{\delta m} \quad (2)$$

Where, F_t is the driving force; F_w is air resistance; F_f is rolling resistance; δ is rotational mass conversion factor, among which, the conversion coefficient of rotational inertia of parallel hybrid vehicles is,

$$\delta = 1 + \frac{I_W + (I_e + I_m i_m^2) i_g^2 i_0^2}{m r_r^2} \quad (3)$$

Where, I_W is the total moment of inertia of wheel; I_e is the sum of the moment of inertia of all engine rotating parts connected to the engine crankshaft; I_m is the total moment of inertia of all rotating parts connected to the motor shaft; i_m is dynamic coupling speed ratio; i_g is transmission speed ratio. In the CYC_UDDS cycle condition, hybrid vehicle can obtain the best dynamic and economic performance when the peak power of motor is 45 kw by backward simulation.

2.3. Battery parameter selection

The battery parameters mainly include power, energy and SOC (State of Charge).

The charging and discharging power of the battery should meet the power demand of the motor and match the power of the engine. The power of the battery should be greater than the maximum power of the motor, the maximum required power of the battery is:

$$\mathrm{p}_{ess} = \frac{p_{\varepsilon \max}}{\eta_\varepsilon} \quad (4)$$

Where, P_{ess} is the maximum power required by the battery.

The total energy of the battery according to the continuous driving distance under the pure electric mode:

$$E_b = \frac{(mgf + \frac{C_D A u_a^2}{21.15}) S_a}{3.6 \eta_t \eta_e \eta_d (SOC_H - SOC_L)} \quad (5)$$

Where, E_b is the total energy of the battery; u_a is the average speed; S_a is the range of continuous driving at the average speed; SOC_H is the initial SOC value. SOC_L is the termination SOC value.

After a long period of stable operation, the SOC changes of the battery of the parallel hybrid car should be as small as possible, so as to minimize or avoid the deep charge and discharge of the battery, so as to reduce the battery loss and prolong the service life of the battery. The total energy of the lithium ion battery selected in this paper is 17kwh, and the initial SOC value is 0.7.

III. Control Characteristic Analysis

3.1. Degree of hybridization

The degree of hybridization is the percentage of the output power of the electric system in total power of the power source:

$$H = \frac{p_m}{p_m + p_e} \times 100\% \quad (6)$$

Where p_m is the motor power; p_e is the engine power.

According to the different proportion of power output of electric system, hybrid power system can be divided into mild, moderate and severe, among which, moderate hybrid power system is the most mature technology at present, and the most widely used type of degree of hybridization is more than 30%. Considering the factors of emissions, fuel consumption, production cost and so on, this paper adopts moderate hybrid degree, which is about 30%.

3.2. Vehicle control strategy

Vehicle power train controller realizes the control of the power system and the vehicle energy management, as shown in Fig.1. It can allocate the motor and engine power output, manage the charge and discharge of battery, realize the optimal allocation of energy, make engine, motor and battery work harmoniously, get the best balance among fuel economy, pollutant emission and power performance [3]. Fuzzy control forms fuzzy rules based on expert experience, the sensor signals is blurred, and the output signal is obtained after the fuzzy reasoning. The fuzzy control technology has strong adaptability and does not rely on accurate models, which is suitable for the control of the power system of hybrid vehicles [4].

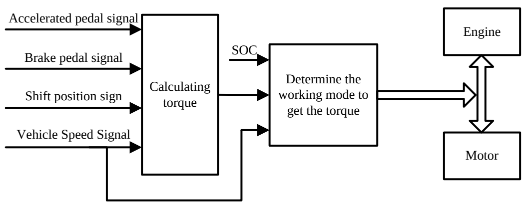


Fig.1 Schematic diagram of energy management strategy

When the starting condition and total torque demand are negative, the control law of fuzzy control strategy is carried out by the logic threshold control strategy [5].

When the battery SOC is in the normal range, the total required torque of the vehicle is mainly provided by the engine [6]. When the required torque exceeds the torque provided by the optimal efficiency area of the engine, the engine is kept in the efficient working area, and the rest torque is provided by the motor as auxiliary torque.

When the battery SOC is low, the engine is operating as efficiently as possible and provides additional torque over the required torque to charge the battery through the generator.

When the battery SOC is high, the motor provides the torque in the starting condition of the vehicle [7]. In the process of driving, the motor works in coordination with the engine to make the engine work in the optimal area as far as possible, and the remaining torque is provided by the motor.

IV. 4. SYSTEM SIMULATION AND RESULT ANALYSIS

4.1. Vehicle parameter matching design verification simulation

Through simulation, the characteristics diagram can be obtained, such as the SOC peak change curve of the battery, the exhaust emission, the demand torque, the engine torque and the motor torque. Fig.2 is the CYC-UDDS road cycle diagram.

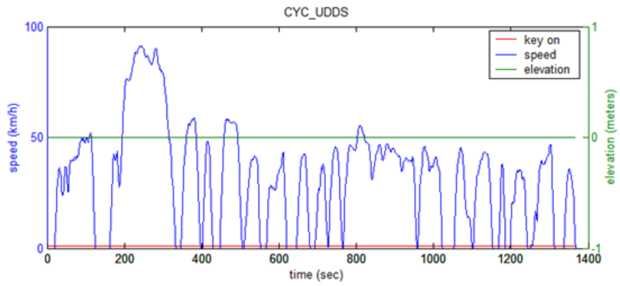


Fig.2 CYC-UDDS road cycle

Fig.3 shows the change of SOC peak value of storage battery. It can be seen from the figure that the SOC value fluctuates up and down within the set range, which basically achieves the charge and discharge balances, the hybrid power system runs well, and the fluctuation range of SOC is around 0.03, which has little change, and is beneficial to prolong the life of storage battery.

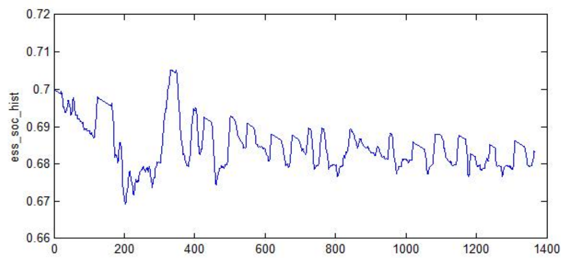


Fig.3 Change of SOC peak value of storage battery

Fig. 4 shows the exhaust emissions chart. From the chart, it can be seen that the exhaust emissions of the engine in the early stage of operation after starting is relatively large, which is related to the factors such as engine coolant temperature and lubrication, etc. With the running of the car, the engine is gradually running stable and the exhaust emissions decreases, reflecting better emission performance.

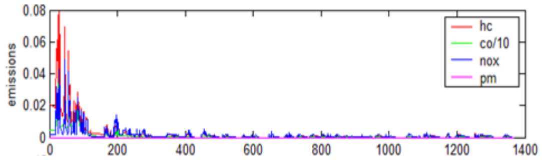


Fig.4 Exhaust Emissions

Fig.5 shows the required torque diagram at the input end of the torque coupler. Fig.6 and Fig.7 respectively show the output torque diagram of the engine and the output torque diagram of the motor. It can be seen from the output torque diagram of the engine and the motor that when the required torque is positive, most of the power is provided by the engine. When the SOC of the battery is higher than the set minimum discharge value, the motor provides auxiliary torque. When the required torque is negative, if the SOC of the battery is less than the limit value, the motor is mainly responsible for generating braking force and energy recovery and storage.

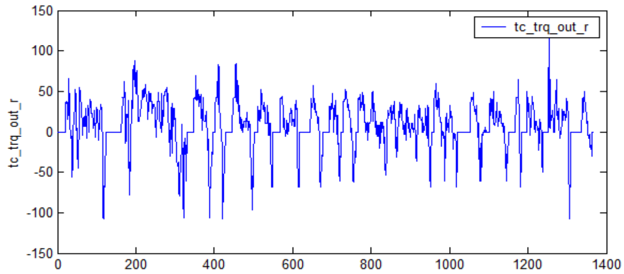


Fig.5 Total required torque diagram

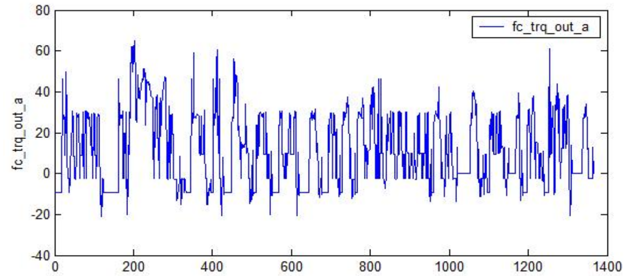


Fig.6 Output torque of the engine

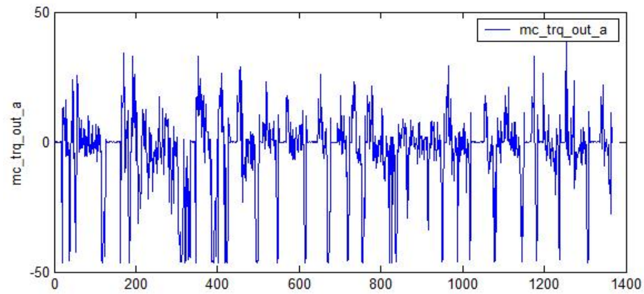
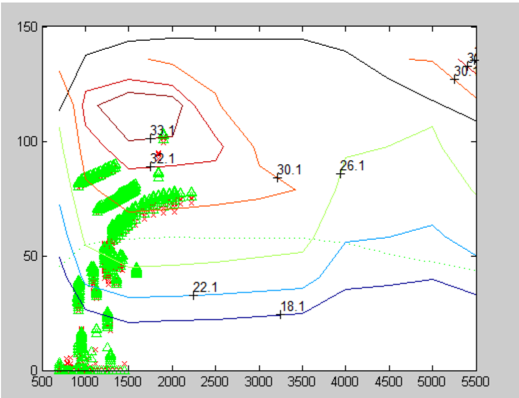


Fig.7 Output torque of the motor

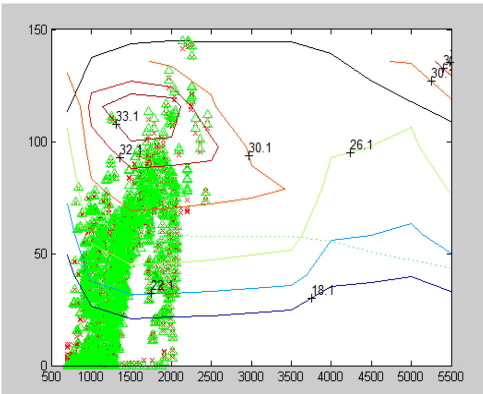
4.2. Analysis of simulation results of energy management strategy

Under UDDS and EUDC conditions, the hybrid power system control based on fuzzy logic control strategy and electric assistance control strategy is simulated. From the simulation results, it can be seen that under the above two road cycle conditions, PHEV using fuzzy logic control has a lower fuel consumption and emission than using electric assistance control, and the dynamic performance has a certain improvement.

Fig. 8 is the comparison of engine working points under fuzzy control and electric assistance control. It can be seen from the figure that the engine working points of hybrid power system using fuzzy control is more concentrated in the high efficiency area, and the fuel economy and emissions are better than those using electric assistance control. Therefore, it can be explained that the fuzzy control strategy is more reasonable than the electric assistance control strategy.



(a) Fuzzy control



(b) Electric assistance control

Fig. 8 Comparison of engine operating points under two control strategies

V. CONCLUSION

Combine with the research status of hybrid electric vehicle at home and abroad, the matching design of hybrid electric vehicle power system is taken as the content, the fuzzy control strategy of parallel hybrid electric system is put forward, the hybrid power system is modeled, simulated and analyzed. By comparing the fuzzy control strategy with the electric control strategy, the conclusion is drawn that the working point of the hybrid power system engine with fuzzy control is more concentrated in the high efficiency area, which verifies the feasibility of the design scheme and provides a basis for the development and improvement of the hybrid power system.

VI. Acknowledgements

The paper is supported by the Youth Talent Innovation Project (BZXYQNLG201607).

REFERENCES

[1] F.H. WANG, Y. LIU. Research Status of Control Strategy for Hybrid Electric Vehicle. *Mechanical Design and Research*, 24 (3), 2008: 39-42.

[2] Y.H. ZHANG, Y.Q. WANG. Design and Simulation of Fuzzy Logic Control Strategy for an SHEV. *Lubrication andSealing*, 4 (12), 2009: 45-47.

[3] F. YANG, S.Q. SUN. Parameters matching and optimization of parallel hybrid electric vehicle powertrain. *Mechanical Transmission*, 2011, 34 (7): 56-61.

[4] A.N. CHEN. Fuzzy logic control of power system for the parallel hybrid electric vehicle.*Coal Mining Machinery*, 23 (8). 2002: 26-27.

[5] J.G. SUN.Study on Fuzzy Control strategy for a Plug-in Parallel Hybrid Electric Vehicle.*Mechanical Transmission*, 32 (2), 2008: 57-59.

[6] N. ZHAO. Design and simulation of fuzzy control strategy of plug-in parallel hybrid electric vehicle. *Machine Tool and Hydraulic*, 36(1), 2008: 37-40.

[7] H. LONG. A research on torque distribution strategy of parallel hybrid electric vehicle based on advisor.*Journal of Mechanical Engineering*,40(8), 2004: 24-29.