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Parametric Matching of Drivetrain For Parallel Hybrid Electric Vehicle

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Abstract

Based on the software ADVISOR2002, the simulation modal of the assembly power and vehicle of the Parallel Hybrid Electric Vehicle (PHEV) has been set up. With the control targets for power characteristic and for fuel characteristic, this paper still considers the state of charge meanwhile; this thesis presents a simulation analysis of the PHEV and the influence on vehicle characteristic by component parameters of drive train, and studies the parametric choice and proper parametric matching among drive train component.

Keywords*: Parallel Hybrid Electric Vehicle, Parametric Matching, Computer Simulation*

1. Introduction

Conventional vehicles operate on the principle of internal combustion engine (ICE) that runs on fossil fuels (gasoline or diesel) from oil deposits that are millions of years old. ICE vehicles emit carbon dioxide, hydrocarbon, sulphur oxides, carbon monoxide and hydrocarbon through their tailpipes [1]. The gases account for global warming through greenhouse gas effects and pollution effects which are harmful to both environment and lives. Therefore, reducing negative impact of ICE emission is one of the most urgent issues of modern society [2, 3].

Compared to conventional internal combustion engine vehicles, Hybrid electric vehicles (HEV) incorporate more electrical components featuring many available patterns of combining the power flows to meet load requirements. There has been a few number of literature surveys on HEV topic. Ref. [2] describes the mathematical modeling, analysis, and simulation results of a novel electrical variable transmission (EVT) for a series-parallel hybrid electric vehicle (SPHEV). Sezer [4] presents a series-parallel hybrid electric vehicle design procedure from design stage to implementation. In [5], Zhu builds an optimal torque based fuzzy logic control strategy for parallel hybrid electric vehicle. The controller is designed based on battery state of charge, electric motor speed, and a relationship between the totally required torque and the optimal engine torque. To enhance HEV performance in terms of fuel economy and emissions, Desai presents an efficient multi-objective genetic algorithm to optimize powertrain component sizes as well as fuel economy and emissions for a parallel HEV. Bowles [6] describes a control strategy for the energy management of a PHEV equipped with a continuously variable transmission (CVT). Results are presented highlighting the dynamic behavior of the model, as well as the fuel consumption normalized to a base case.

Hybrid Drive system has series, parallel and hybrid three forms.Parallel in composition is closer to the traditional vehicle power transmission system [7], Less technology development difficulties, which is suitable for technology development according to the existing conditions. Evaluation and comparison of different structures of hybrid vehicles, as well as the specific structure and different parameters of hybrid vehicles performance,mostly use computer simulation technology platform, which is based on Matlab/Simulink environment, the ADVISOR is the most widely used under the computer environment to model and simulate technology platform.ADVISOR can be used to quickly predict the vehicle dynamic performance and

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economic performance, evaluate the pros and cons of the vehicle control strategy and optimize hybrid parameters [8, 9]. This article takes Figure 1 of determined structure of parallel hybrid electric vehicle drive system as an example and drive line matching study , which is also based on ADVISOR2002 by means of computer simulation, the model shown in Figure 2.

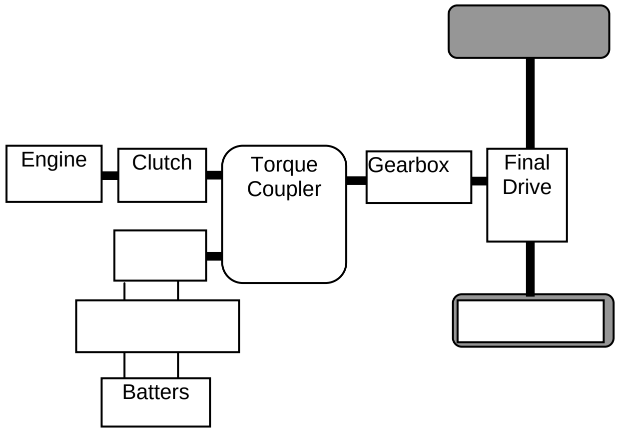

Figure 1. Sketch Map of Drivetrain of PHEV

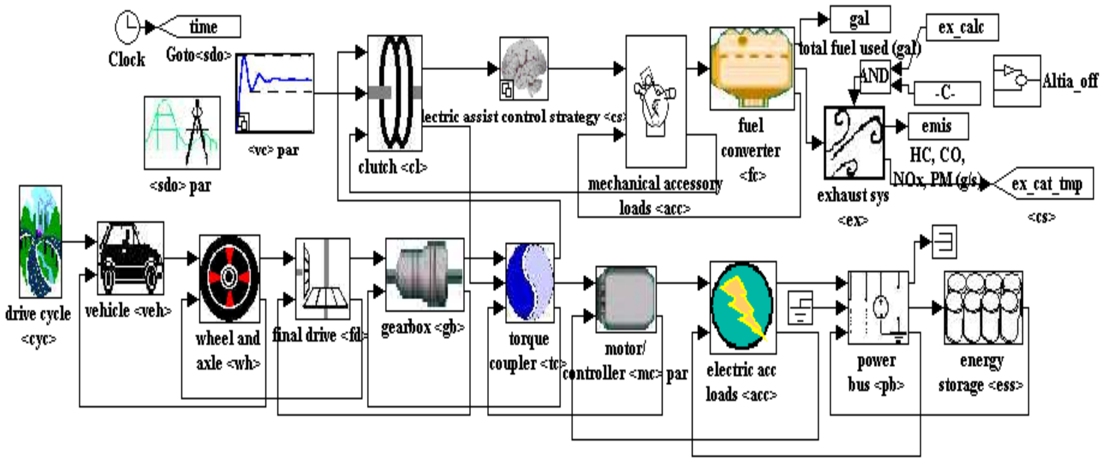

Figure 2. Simulation Model of PHEV

2. Control Objectives of PHEV
2.1. Determination of Power Performance Indicators

The selection of hybrid drive system components parameters directly influences the vehicle dynamic performance indicators. Reference to the requirements of the national standards, in this paper the dynamic performance indicators of PHEV are as follows:

(1) Driving mileage In the hybrid vehicles whose Power is maintained , the continued driving distance has nothing to do with the capacity of the battery pack,and is mainly determined by the volume of the fuel tank.

(2) Maximum speed Reference to test method about electric vehicle energy consumption rate and continued driving mileage from the GB/T18386-2001 , this selects a maximum speed of 170km / h.

(3) Climbing performance The automotive vehicle can travel at the speed of 20km / h on the greater than 25% of the ramp.

(4) Acceleration performance Car acceleration performance largely determines the size of the car back-up power, the cars of 0 ~ 100 km / h acceleration time is 12 ~20s.

Reference[10] to the electric vehicle acceleration performances in the experimental cycle suburban driving cycle and cars from GB/T18386-2001 , acceleration time of design vehicles of 0 ~ 100 km / h is of not more than 15s.

2.2. Vehicle parameters

(1) Car type

The four-door and five-seater, front driver.

(2) Overall dimensions

Total length:4300~4400 mm.

Total width : 1600~1700 mm.

Total height:1400~1450 mm.

(3) main components of the drive system

Engine: four-stroke gasoline engine.

Motor: three-phase AC induction motor.

Batteries: nickel metal hydride batteries.

Transmission: five-speed manually.

(4) Other parameters

Wind drag coefficient:0.34.

Wheel rolling radius:0.28.

3. Determination of Parallel Hybrid Electric Vehicle Mixing Ratio

It is shown in Figure 3, where relationship exists between the engine power and motor power in the hybrid vehicle.

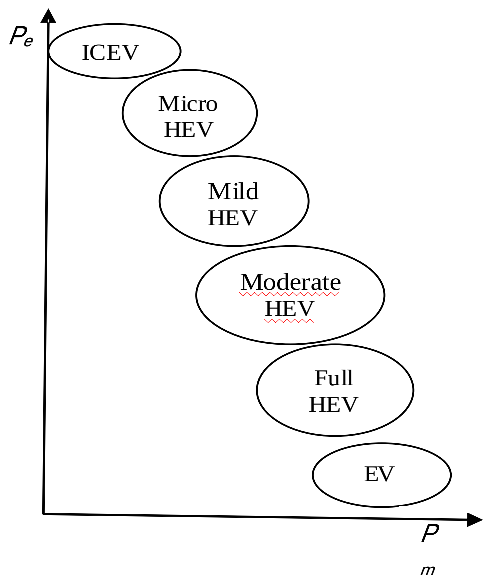

Figure 3. Relationship of Pe and Pm

Parallel hybrid drive system mixing ratio is defined as:

$$R = \frac{P_m}{P_m + P_e} \tag{1}$$

Where R ——mixing ratio;

P_m——motor power (kW);

P_e ——Engine power (kW)。

The Figure 3 shows that with the increase of mixing ratio, drive system will make from the traditional cars, the electric booster hybrid electric vehicle to the driving range the extended hybrid vehicles, electric vehicles transition.

Electric vehicle battery technology is not yet mature, battery specific power and specific energy are low, and the cost is high, the mixing ratio of choice will affect the quality and cost of the vehicle, at the same time it will cause the vehicle layout for hybrid vehicles difficulties and other problems.the relationship of Hybrid vehicle mixing ratio with the vehicle curb weight is that in the case of a certain total power,the greater the mixing ratio is , the greater the vehicle mass is, the greater of the power motor is, the higher cost of the corresponding vehicle is.For hybrid vehicles, ,it is more appropriate to use the parallel electric booster-type drive system under the premise of meeting the control objectives , which takes the mixing ratio of less than 0.5.

4. Parallel Hybrid Electric Vehicle Drive Train Parameters Matching

PHEV drive system parameters matching is reasonable to meet the power performance, fuel economy and emissions to determine the parameters of the various components [11]. The drive train of PHEV includes the engine, motor, battery, torque synthesizer, transmission and main reducer.

4.1. Engine Parameters Matching

Hybrid car engine parameters matching should be satisfied: the engine alone drives at the maximum speed of 120km / h; engine individually drive the vehicle at the 20km / h speed at greater than 10% of the ramp; in addition to satisfy the mixing ratio less than 0.5 ,also it should meet driving power performance and better fuel economy when the engine alone drive and the mixed with motor .

Engine power is an important parameter of engine parameters matching.Has not been identified in the parameters of the motor and the battery , The initial choice of engine power is based on the dynamic performance of the vehicle in the driving alone.

The car required maximum power $p_{\max}$ can be obtained by the following formula by automobile theory:

$$p_{\max} = \frac{1}{\eta_t}\left(\frac{mgf}{3600}V_{\max} + \frac{C_d A}{76140}V_{\max}^3\right) \qquad (2)$$

where $V_{\max}$ ——Maximum speed(km/h)(value of 170);

η_t —— The transmission efficiency (value of 0.90);

m ——Total weight(kg)(value of 1600);

f ——Rolling resistance coefficient (value of 0.012);

A —— Windward area (m2) (value of1.84);

C_d ——Drag coefficient (value of 0.34).

Should be added 10% reserve coefficient when maximum power is required according to the above equation [12], The last will get the maximum power is the sum of the hybrid car engine and motor power 60kw.

To Simulate and calculate vehicle performance .it is required to control mixing ratio within a range of less than 0.5 and select a different mixing ratio of the different mixing ratio of a hybrid vehicle engine driven individually.Figure 4 is a simulation result of the different mixing ratio of the engine individually driving vehicle performance.As can be seen from the figure, with the mixing ratio increasing, the time of engine alone driving vehicle at 0 ~ 100km / h speed acceleration becomes longer,Grade ability becomes smaller at the speed of 20km / h, maximum speed and reduce fuel consumption is reduced.in accordance with the above-identified vehicle dynamic performance indicators of individually driving, it initially selects the mixing ratio the range from 0 to 0.4,That is, the power of the engine in the range of 24 ~ 60kW.

4.2. Motor Parameters Matching

The motor must satisfy the following requirements: motor and engine hybrid driving should meet vehicle dynamic performance and fuel economy indicators; that motor vehicle power impacting on dynamic power further narrows the range of mixing ratio.

A simulation result of the different mixing ratio of the hybrid drive vehicle performance was obtained, according to the simulation results, it can draw the following conclusions:

(1) When the vehicle total power is 60kw, the mixing ratio range of 0.2 to 0.5 has little influence upon the highest speed , acceleration time of 0 ~~ 100km /h and maximum climbable gradient basically , if you want to improve vehicle dynamic performance of the hybrid car, You must increase the total power of the vehicle.

(2) Whether mixing ratio to take any value within the range of less than 0.5, the total vehicle power of 60kw, the hybrid driving vehicle dynamic performance of a hybrid vehicle can achieve technical indicators.

Considering the engine alone and hybrid driving performance,when the total power is 60kw and the the hybrid cars mixing ratio is 0.3, the maximum speed of the hybrid cars is 177.7km / h, the maximum climbable gradient is 49.7% at the speed of 20km / h , acceleration time is12.6s at the speed of 0~100km/h . Therefore, when the mixing ratio is 0.3 , it can meet the power requirements of hybrid vehicles. Finally the parameters of the engine and the motor is , the engine, 42kw; motor 18kw.

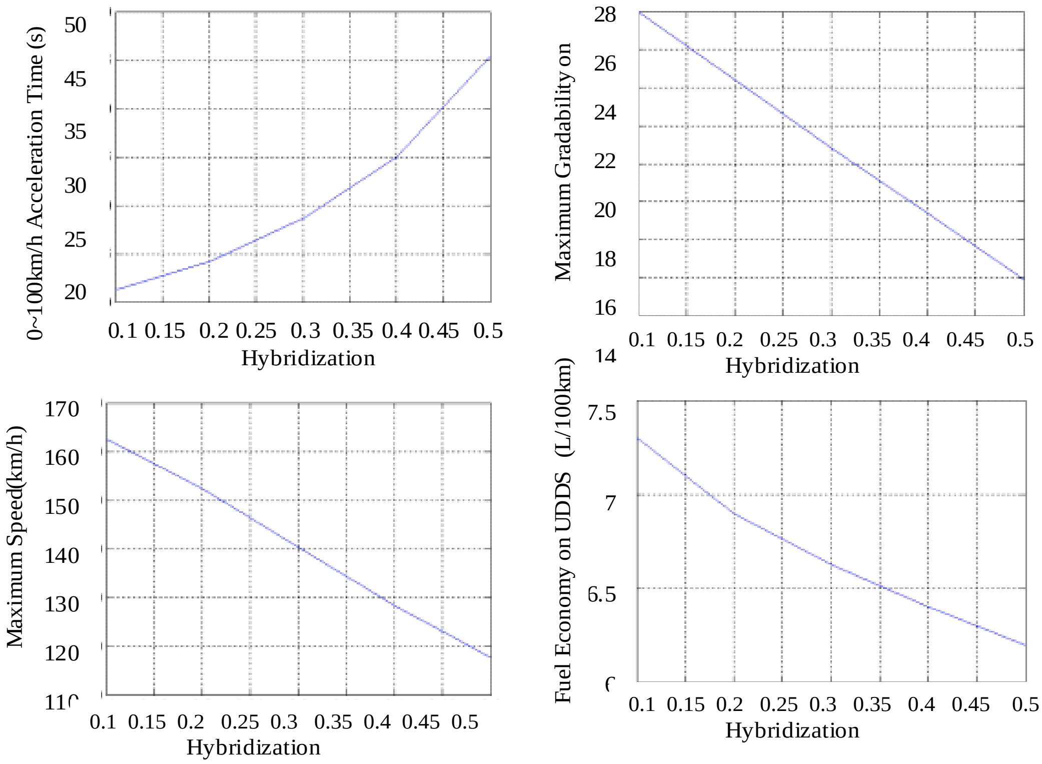

Figure 4. Effects of Bridization of Eengine-drive alone on Performance of overall Vehicle

4.3. Battery Parameters Matching

Nikel-mental hydride (NiMH) batteries are high energy density, high power density, good environmental protection, longer service life, can fast charge and discharge curve is flat. Currently NiMH battery for hybrid vehicles is preferred as energy storage system.

Match for the power to maintain hybrid car battery parameters, it mainly considers that the battery energy should meet the requirements of the vehicle driving conditions in accordance with the standard cycle; when the battery match vehicle driving conditions in accordance with the standard cycle energy demand at the same time, after the end of the cycle.the energy in the battery must be able to be maintained at an acceptable level, i.e. the SOC (state of charge) can be maintained at an acceptable value after the end of the cycle.

Figure 5 is the number of single cells, where voltage affects the performance of the hybrid vehicles, the number of single cells basically had no effect on the power of the vehicle from the figure, fuel economy decreases with the increase of the number of battery, when the number reached 50 knots, fuel economy has stabilized. The vehicle cost with battery increasing in the number will increase at the same time, voltage of parallel hybrid vehicles should be 288 ~~ 350V according to research . Figure 6 is the hybrid electric vehicle battery SOC time course of the curve, which is based on the above matching and experiencing two standard driving cycle of the UDDS (U.S. EPA city Dynamometer operation cycle) and HWFET (U.S. EPA highway fuel economy test mode), SOC value of the battery is maintained at 0.64 or so.

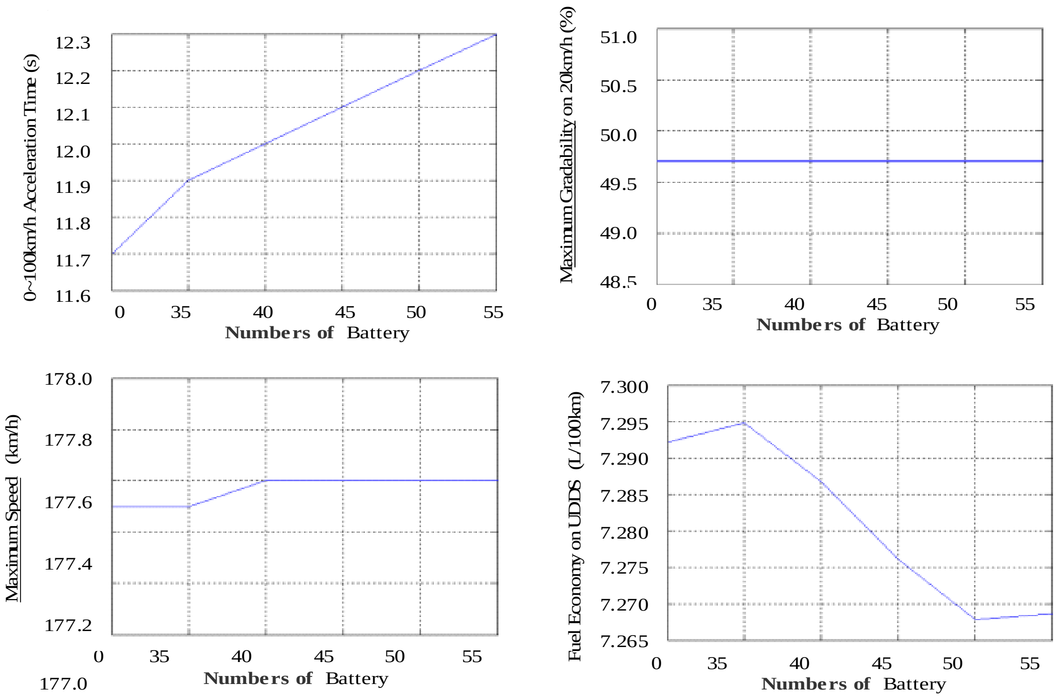

Figure 5. Effects of Quantity of Battery on Performance of HEV

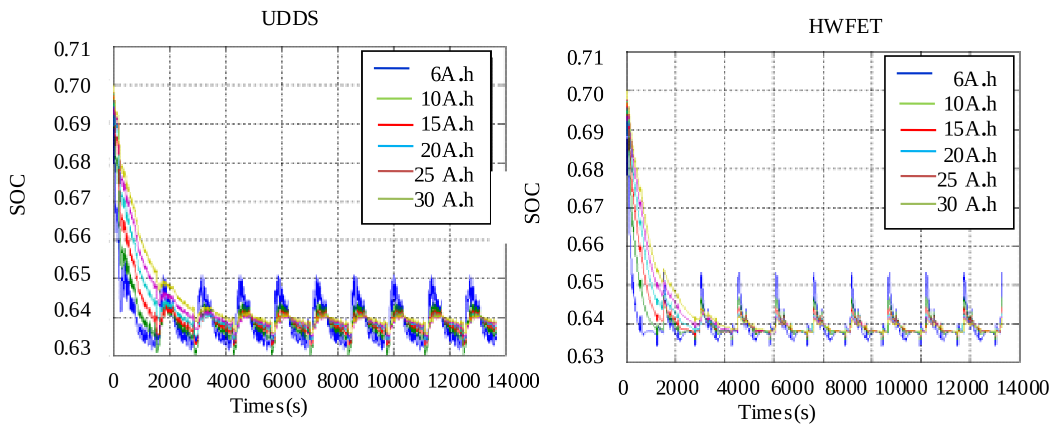

Figure 6. Curve of SOC for Power Battery

4.4. Torque Coupler

Parameters matching of parallel hybrid electric vehicle is determined on the basis of meeting vehicle dynamic performance. Necessary to ensure that the motor and engine can output maximum power. speed ratio from the motor shaft to the engine shaft should be determined by the ratio of the maximum speed of the motor and the maximum engine speed. speed ratio of Torque couper is determined by the following formula:

$$i_{tc} = \frac{n_{mrmax}}{n_{enmax}} \tag{3}$$

where $n_{mr\max}$ ——Maximum motor speed(rpm);

$n_{en\max}$ ——Maximum engine speed(rpm);

i_{tc} ——Torque couper Ratio.

4.5. The speed Ratio of the Transmission

Hybrid vehicles in general convert from a traditional car, so the speed ratio of the transmission and main reducer still use the traditional car speed ratio.

In summary, the hybrid vehicle speed ratio of torque coupler and transmission are shown in Table 1.

Table 1. Speed Ratio of Torque Coupler and Transmission

first gear	3.445	fifth gear	0.85
second gear	1.944	reverse gear	3.167
third gear	1.3704	main reducer	3.941
fourth gear	1.3023	torque coupler	1.7368

5. Conclusion

By means of simulation,the paper study that the hybrid vehicle drive train parameters have an effect on vehicle dynamic performance, fuel economy and battery energy , and match the design of hybrid vehicles.Taking into account factors such as the quality of the vehicle as well as vehicle layout, the mixing ratio of the parallel hybrid electric vehicle is determined the value of 0.3 (parameters of the engine and the motor: engine, 42kw; motor, 18kw); considering that the number of NIMH battery selected is50 (voltage 335V), the battery capacity is 15 $A \cdot h$. So that it can complete hybrid vehicle drive train parameters matching.

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