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Study on Fuel Economy Performance of HEV Based on Powertrain Test Bed

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Short Abstract

This paper introduces the configuration and design of powertrain test bed of dual-motor hybrid system, based on the test bed, optimazing the torque distribution control strategy of hybrid control system of B70HEV. The result of test proves that the optimized hybrid control strategy based on the powertrain test bed improves the fuel economy performance obviously; it also provides a convenient and dependable development platform.

Keywords：car,HEV, efficiency, powertrain, vehicle performance

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1 Introduction

Compared to conventional vehicle, the hybrid vehicle adds high volt battery-motor system, there are two power systems, and one of them is possible to work in drive mode and brake mode. The gear selection and the ways of energy distribution between engine and high volt system can affect the fuel economy performance. The path of energy of hybrid is more complex than conventional vehicle, not only the efficiency of engine and driveline, but also the efficiency of motor and generating, the efficiency of battery charging and discharging should be considered. It is difficult to obtain accurate total efficiency from fuel to axles by calculation. If we can't obtain accurate components efficiency， it is hard to optimize torque distribution control strategy of hybrid control system. So that FAW develops fuel economy optimization based on FAW-TMHTM powertrain [1] test bed, the accurate total efficiency of powertrain can be obtained through powertrain test bed directly. It is very useful for fuel economy performance optimization.

2 The design of powertrain test bed

2.1 The configuration of powertrain

FAW-TMH^{TM} powertrain is constituted of engine, clutch, AMT, Belt Driven Starter Generator (BSG), traction motor(TM), differential and axles, the BSG is connected to engine by belt; the traction motor is connected to output of AMT by chain.

Table1 powertrain parameters of B70HEV

Type	Parameter	Value
Vehicle	Vehicle weight	1530 kg
Engine	Displacement	1.497 l
	Power	74 kW
	Torque	135 Nm
Traction Motor	Max power	40kW
	Max speed	7600 rpm
BSG Motor	Max power	10 kW
	Max speed	12000 rpm
Battery	Type	Lion
	Capacity	5.3 Ah
	Voltage	320 V
	Max discharge power	29 kW
Transmission	Type	5 Speed AMT

2.2 The configuration of powertrain test bed

The fuel is supplied through fuel consumption meter. The fuel flow can be measured by fuel consumption meter. The battery simulator supplies electric power to inverter of motor, the status of battery is simulated by battery simulator (e.g. SOC, SOH, battery temperature, resistance etc), and the motor bus bar voltage and current can be measured by battery simulator. There are two dynamometer machines connected to axles, and actual torque of axles will be measured, the controller of dynamometer machines will control the speed of dynamometer machines flowing the calculating result of virtual environment. Virtual environment includes driver model, vehicle model and road model. The resistance force of vehicle will be calculated by vehicle model, road model and the measured the torque of axles will be considered as drive torque, and then the vehicle model will calculates the target speed of axles by drive torque and resistance torque of vehicle. Driver model will calculate target position of acceleration and brake then host computer transition it to HCU, and BSG torque, TM torque and engine torque will be controlled by HCU.

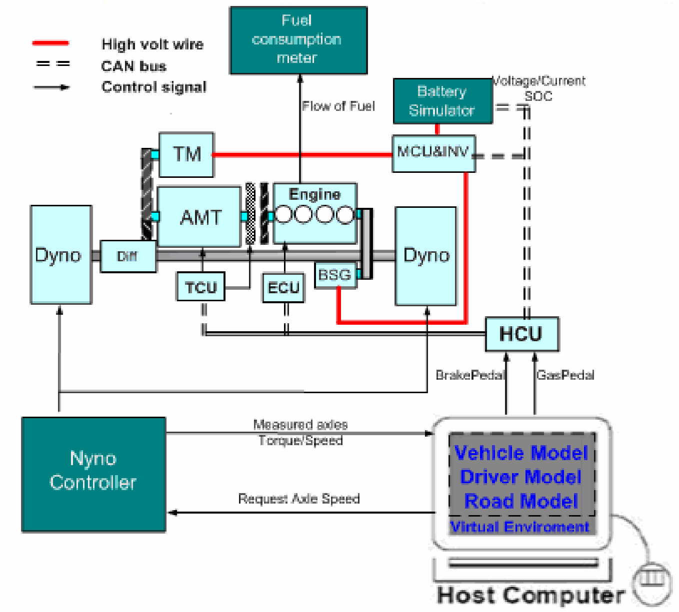

Figure1: Configuration of powertrain test bed

3 Fuel economy optimization based on powertrain test bed

3.1 Test of powertrain efficiency

As to the B70HEV, the consumption of powertrain is only gasoline, and the effective power of powertrain is the power used for driving vehicle. We define the efficiency of powertrain as the effective use of energy by powertrain. As to conventional vehicle, the effective power is the output power of axles, when powertrain consumes gasoline. But for hybrid electric vehicle, one part of effective power (P_1) is the output power of axles,

$$P_1 = T_{axle} \cdot n_{axle} \qquad (1)$$

Hereinto： T_{axle} —axles torque measured by dynamometer machines, n_{axle} —axles speed measured by dynamometer machines.

Another effective power (P_2) come from electric power (P_e), when motor drive vehicle, P_e will convert to effective power at output of axles (P_2). When battery charges, P_2 will be affected by charging, discharging and motoring. When battery discharges, P_2 will be affected by motoring[2].

$$P_e = -V_{batt} \cdot I_{batt} \qquad (2)$$

$$\begin{cases} P_2 = P_e \cdot \bar{\eta}_{battcharg} \cdot \bar{\eta}_{battdischarg} \cdot \bar{\eta}_{mot} \\ P_2 = P_e \cdot \bar{\eta}_{mot} \end{cases} \quad (3)$$

Hereinto： V_{batt} —motor bus bar voltage measured by battery simulator, I_{batt} —motor bus bar current measured by battery simulator, $\bar{\eta}_{battcharg}$ —battery average charging efficiency in driving cycle, $\bar{\eta}_{battdischarg}$ —battery average discharging efficiency in driving cycle, $\bar{\eta}_{mot}$ —average motor efficiency in driving cycle

The input power of powertrain is

$$P_{in} = Q_{fuel} . \rho . q$$

Hereinto： Q_{fuel} —fuel flow measured by fuel consumption meter, ρ —fuel density, q —fuel heat value.

The efficiency of powertrain is

$$\bar{\eta}_p = \frac{p_1 + p_2}{p_{in}} \quad (4)$$

Based on the formula above, we can test the efficiency of powertrain based on powertrain test bed. Take constant speed (70km/h) drive for example (Table2), in order to maintain the vehicle speed, the torque of axles of powertrain should give an output of 103 Nm, the speed of axles is 63rad/s, which is calculated by vehicle model. Under the condition of torque and speed of axles, we can select different gears and distribute different engine torque, different TM torque and different BSG torque. In this way, we can attain the efficiency of powertrain under different energy distribution ways.

Table2 efficiency of powertrain under different energy distribution ways

Status of powertrain				Input of powertrain	Output of powertrain				$\bar{\eta}_p$ （%）
Gear	BSG Torque （Nm）	Combustion Torque （Nm）	TM Torque （Nm）	Q_{fuel} （l/h）	I_{batt} (A)	V_{batt} （V)	T_{axle} (Nm)	n_{axle} （rad/s）	
5	0	55.405	0	3.546	0	320	104.79	63.16	0.204
5	-6	65.016	0	4.256	-5.85	320	103.71	63.17	0.205
5	-18	85.52	0	5.403	-19.47	320	100.57	63.16	0.215
5	-18	106.333	-10	6.689	-30.17	320	101.92	63.16	0.212
5	0	73.786	-10	4.595	-10.2	320	102.34	63.17	0.209
5	0	88.533	-20	5.553	-19.99	320	103.10	63.16	0.214
5	0	105.043	-30	6.58	-30.78	320	100.61	63.15	0.216
4	0	48.278	0	3.5168	1.22	320	103.59	62.21	0.239
4	-6	58.492	0	3.9963	-7.14	320	104.33	62.21	0.246
4	-16	76.987	0	4.9252	-20.27	320	105.33	62.21	0.244
4	0	64.137	-10	4.2665	-9.68	320	105.57	62.23	0.242
4	0	76.341	-20	4.8972	-19.61	320	104.95	62.22	0.242
4	0	91.395	-30	5.6476	-28.28	320	105.44	62.21	0.235

There is no fuel consumption under idle stop mode, so we don’t have to test the efficiency of powertrain. The efficiency of powertrain is zero under idle warm mode, because both the values of P_1 and P_2 are zero, but there is fuel consumption.

3.2 Control strategy based on the efficiency of powertrain

The efficiency of powertrain under different energy distributions can be tested In the NEDC cycle (shown in figure2). For certain drive cycle, total output work of powertrain is known, so we can improve the efficiency of powertrain to improve fuel economy performance. The control strategy is set threshold value of powertrain efficiency. If the peak powertrain efficiency of operating point is higher than the threshold value, the powertrain will work in hybrid mode, and energy distribution ways should refer to peak powertrain efficiency. Otherwise, the powertrain work in EV mode, in which the energy consumption in low efficiency can avoid. When SOC drops in whole cycle, threshold value of powertrain efficiency should be adjusted downwards, and which will increase probability of engine work and decrease the probability of EV work. When SOC rises in whole cycle, threshold value of powertrain efficiency should be adjusted upwards, and which will increase probability of engine work and decrease the probability of EV work. Not only we can make sure of the balance of SOC, but also improve the average efficiency of powertrain.

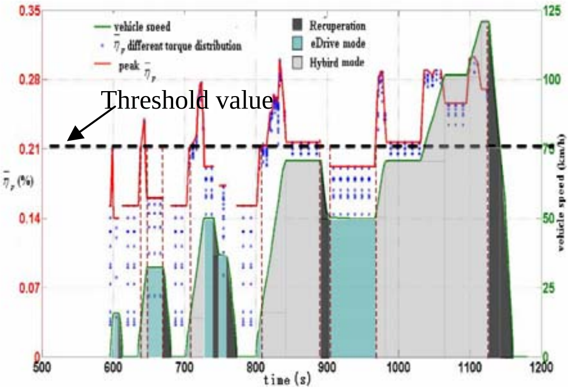

Figure2: The efficiency of powertrain in NEDC

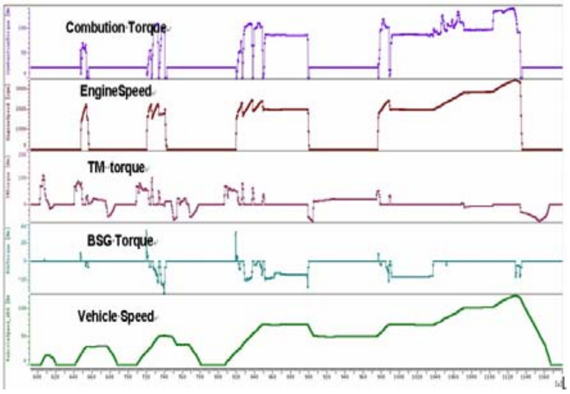

Figure3: The result of this control strategy

To prove the advantage of power train has better fuel economy performance, we compare it with fuzzy logic control strategy under different cycles. The results of two control strategies under different cycles are shown in table 3.We can see from the table that the fuel economy performance of control strategy based on the efficiency of power train under different cycles are better than the fuel economy performance of fuzzy logic control strategy.

Table3: Fuel consumption under different cycles

Cycle / FC (L/100km) / Control strategy	NEDC	1015	UDDS
Fuzzy logic control strategy	5.9	6.1	6
Base on the efficiency of powertrain	5.6	5.9	5.6

4 Summary

The study of powertrain testing technology of dual-motor hybrid system not only makes test environment various, but also can evaluate the ways of energy distribution. This work provides guidance for fuel economy performance optimization of hybrid control system. The breakthrough of the test technology can strengthen the competition of hybrid electric vehicle production development.

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