

Study on a Performance of the xEV's core parts using a Real-time Monitoring System

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Abstract

This study evaluated / analyzed parts after collecting / analyzing various data of the core parts like motor, inverter and high-voltage battery equipped in green cars, in real-time for each season and each driving road by using the real-time driving monitoring system. In case of green cars in which high-voltage battery is the main power source, the changes of parts characteristics caused by the external environmental factors are remarkable, which is expected to be used as grounds for life prediction of vehicles and parts in long-term perspectives.

Keywords: monitoring system, automotive components, analysis, xEV

1 Introduction

Due to the concerns about lack of fossil fuel, high oil price policy of oil-producing countries and global warming, globally there are more increased demands for eco-friendly green cars(xEVs). Green cars are needed to have a new multi-purpose test/evaluation system for improvement of energy efficiency and verification of the performance of new power system, and as an alternative, a real-time driving monitoring system was suggested by Korea Automotive Technology Institute[1, 2].

Getting out of the typical driving test method which is the offline method that collects data for certain period of time and then analyzes/stores it in additional strong device, the real-time driving monitoring system is based on the online method in which data measurement, transmission and analysis can be done simultaneously. With its various functions including massive data processing for long-term like several months, shadow monitoring of positive concept and data

automatic analysis, it is possible to apply it to verification of auto parts or vehicles and evaluation of reliability

Since the performance of green cars' core parts and endurance characteristics are such important elements to realize the improvement of green cars' fuel efficiency, it is essential to test and analyze the performance of core parts and endurance. The monitoring system that can acquire information about the external environment and parts equipped in vehicles is effective in labor force/time/cost reduction to acquire such vehicle test data. The real-time driving monitoring system can not only monitor the performance of parts in the level of vehicle without having limitations of time/space, but also analyze data in real-time.

This study evaluated / analyzed parts after collecting / analyzing various data of the core parts like motor, inverter and high-voltage battery equipped in green cars, in real-time for each season and each driving road by using the real-time driving monitoring system. In case of green cars in which high-voltage battery is the main power source, the changes of parts characteristics

caused by the external environmental factors are remarkable, which is expected to be used as grounds for life prediction of vehicles and parts in long-term perspectives.

2 Composition of System and Test Method

2.1 Composition of the Real-Time Monitoring System

The real-time driving monitoring system has many functions like collecting vehicle/parts information, collecting information about parts and control signal of vehicles through diagnostic port, parsing / encoding / compressing data of vehicle and parts gathered from a collecting device and then sending in real-time to a collecting server through mobile communication network, systematically saving received vehicle information in database and providing data analytical environment and test data of parts needed to businesses or special users.

Just like Fig.1, the system is comprised of a vehicle information collecting device(built-in) that gathers information about parts and environment, the real-time wireless transmission terminal(V2M) that sends data received from the vehicle information collecting device to a server and then set the monitoring items and equipment in accordance with configuration file transmitted from the server, a network platform that can collect/analyze data sent through domestic mobile communication network and be remotely interlocked with wireless transmission terminal and the operation center that can save test data, monitor the current test condition and analyze data. Regardless of time and space, it is possible to check the saved data and analysis information through users' PC.

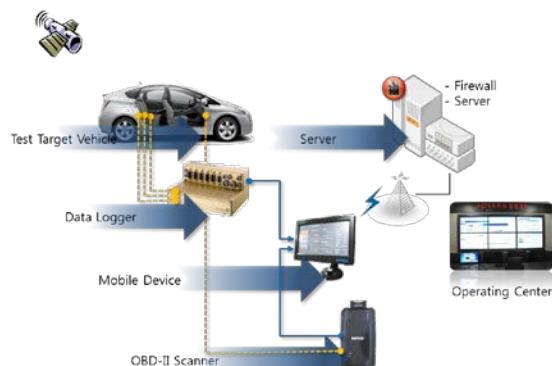


Figure 1: Overall structure of Real-Time Monitoring System

2.2 Specification of Test Vehicles

Driving and analyzing total three cars like one type of HEV and two types of PHEV among advanced green cars, the specifications of each vehicle is like Table1.

2.3 Test Method

Based on the driving data of the real vehicle condition, we analyzed the basic performance of battery, motor and inverter. By driving on the same route of highway, local road and mountain road in summer and winter, we analyzed not only the performance of battery and motor but also temperature characteristics of motor, inverter and high-voltage battery in accordance with different seasons.

2.3.1 Conditions of Driving Road

We drove for the section of 48km highway, 56km local road and 7km mountain road. We acquired data through OTL(OBD-II data Transfer Linker) by attaching temperature/voltage/current sensor and using OBD-II terminal and then saved it in the server in real-time.

Vehicles were driving in its normal mode as one person boarded. We considered that the average and the highest speed could be different in accordance with road conditions even on the same route.

In case of PHEV in which the initial SOC varies in dependent on charging condition, it was principally driving in EV mode. In case of mountain road, however, it was driving in hybrid mode as it was changed into it in the middle of driving.

Table 1: Specifications of test vehicles

Model	Prius III	Volt	Prius Plug-in
OEM	Toyota	GM	Toyota
Production year	2009	2011	2012
Max. Speed(km/h)	180	160	180
Fuel Economy(km/l)	29.2	15.7	40
Motor(kW)	60	111	60
Generator(kW)	42	54	42
Engine(kW)	73	60	73
Hybrid Technology	Full hybrid	Plug-in	Plug-in
Motor Max. Torq.(Nm)	207	368	207
Battery Type	Ni-MH	Li-ion	Li-ion
Battery Capacity(kWh)	1.3	16	4.4

2.3.2 Conditions of Driving Road

Since the high-voltage battery which is the power source of xEV shows big difference in performance in accordance with temperature, the vehicle were running in each summer and winter.

The average driving temperature in summer is about 35°C while the average driving temperature in winter is about 0°C. Driving in accordance with the condition of driving road of 2.3.1 for both summer and winter, it was divided and analyzed based on each vehicle type.

3 Analysis Results & Consideration

3.1 Comparison of Basic Performance in Accordance with Driving Roads

xEVs that use high-voltage battery as a power source show significant differences in power characteristics of the high-voltage battery in accordance with the slope of driving roads, driving speed and drivers' driving habits. And driving motor speed and torque are dependent on the condition of driving roads.

3.1.1 Voltage Output of High-voltage Battery

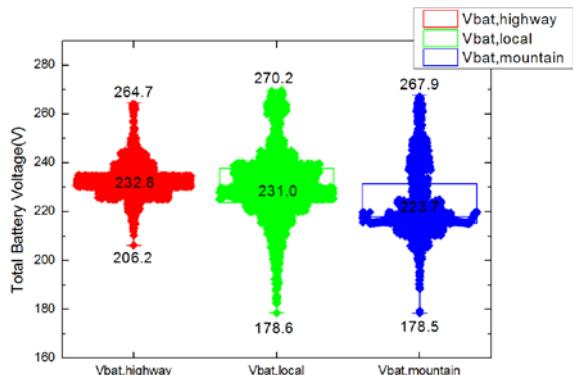


Figure2: Voltage Distribution of High-Voltage Battery

Fig.2 is a diagram of voltage distribution of high-voltage battery in dependent on the road characteristics of highway, local road and mountain road. By using HEV vehicles, the driving was conducted in the same temperature environments.

Just as shown in Fig.2, highway shows the narrowest distribution among them as its battery power was 206.2 ~ 264.7 V because there are almost no ups and downs of speed. Since the use rate of battery is low, the battery level is relatively high.

Compared to highway, local road has wide distribution range as it has lots of ups and downs of speed. Its voltage level is also low as its motor driving rate by using battery is high.

Since there are lots of motor driving in a steep gradient of mountain road, the use rate of battery is high and the overall voltage level is low.

3.1.2 Driving Motor Speed & Torque

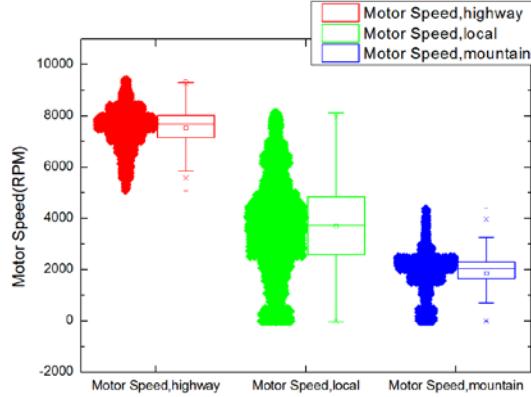


Figure3: Speed Distribution of Driving Motor

Fig.3 shows the speed distribution of driving motor in accordance with driving roads. In case of highway, the change of vehicle speed is small and thereby the distribution of motor speed is the narrowest. Though local road has more frequent stop/go than the one on highway, the speed distribution is widely spread from 0 to 8000rpm. Mountain road has high slope and lots of successive sections of uphill and downhill, there must be lots of parts necessary for engine driving force. So the motor speed is relatively slow around 2000rpm.

Fig. 4 presents the motor torque values at each test driving road. It shows that the motor torque value is low due to the low load in the high speed section, however, the motor torque should be high in the mountain road with steep acclivity

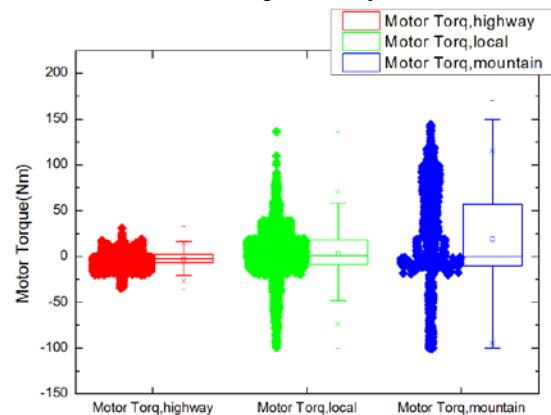


Figure4: Motor Torque(at each driving road)

3.2 Comparison of Basic Performance in Accordance with Seasons

3.2.1 Temperature Changes of Inverter, Motor and High-Voltage Battery

In order to estimate the life of auto parts, it is essential to analyze the parts environment in accordance with surrounding environment. Therefore, we analyzed the temperature changes of motor, battery and inverter in accordance with outside temperature in summer and winter. It is the results of driving on highway and general road for around 2hours and 20minutes.

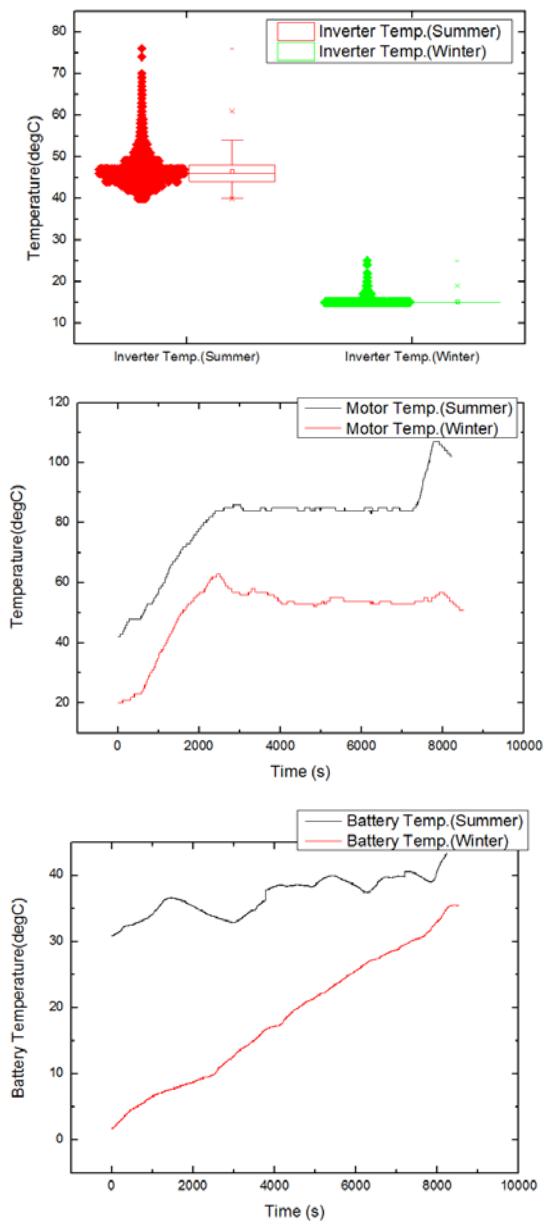


Figure 5: Characteristics of Temperature

As shown in the temperature distribution of inverter illustrated in Fig. 5, the average temperature of inverter is in proportion to the difference of ambient temperature. So the rate of change is the highest in summer.

It is assumed that the cooling of inverter is not going on smoothly because the temperature of coolant is higher in summer than in winter.

Like this, in case of the temperature of motor the difference of most frequent temperature level at each season is in proportion to that of ambient temperature.

Even though the driving test was carried out on the same driving road, the temperature of motor was raised up to 110°C in summer, which showed that it was not effective to cool down the motor in summer.

The temperature of high-voltage battery kept increasing continuously up to 35°C in winter. But in summer the temperature curve showed inflection points, so that we could find out that the battery cooling system was working.

3.2.2 Changes in SOC

The following graph shows the high-speed driving test result for different season, indicating the pattern of changes in SOC during the time from the full charge to the brink of engine operation. This vehicle was equipped with Plug-in Hybrid system, in which the operation of engine precedes the operation of motor and the engine starts when the SOC reaches the certain level below a certain level. Therefore the SOC reduces without recharging. It was identified that the reduction rate of SOC in summer was 1.3 times bigger than in winter, even though the car was driven in the same testing road. It was concluded that the internal resistance of high-voltage battery increased in winter and the nominal voltage reduced along with the degradation of battery performance, so that the SOC reduction rate rose as well.

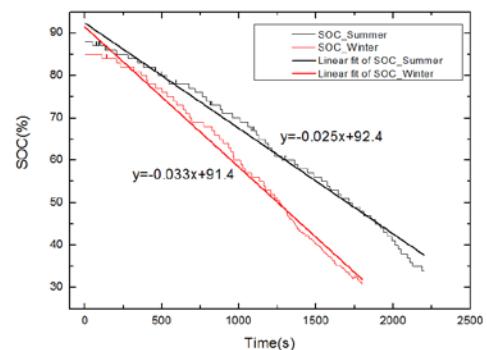


Figure 6: SOC of High Voltage Battery

3.3 Comparison of Basic Performance in Each Vehicle Type

The most remarkable difference in comparison among car models occurred in the part of HV battery. The Prius 3 equipped with Ni-MH battery showed the biggest fluctuation of battery voltage, which was about 80 volts. On the contrary, the Prius PHEV equipped with Li-ion battery showed the smallest fluctuation of battery voltage, which was within 20 volts. That's because the level of battery SOC of Prius PHEV is maintained by recharging the battery when the engine is operating.

Even though the Chevy Volt is equipped with a Li-ion battery, it maintains the average voltage at 360 volts, which is 140 volts higher than that of Prius 3 and Prius PHEV. The number of Li-ion cells in the Prius PHEV model is 56. The 288 Li-ion cells in the Chevy Volt are divided into groups with 96 cells, so that it may provide the battery nominal voltage which is 1.7 times higher than that of Prius PHEV. Accordingly, the battery capacity increases, which leads to the increase of electric current in the same rate. As for the changes in SOC, it is possible to confirm that the range of fluctuation is the biggest in the Chevy Volt, which consumes the battery preferentially, in terms of the numerical values.

Table 2: Results of Driving Test

ITEM		Prius3	Prius PHEV	Chevy Volt
Vehicle speed(km/h)	Max.	127	140	106
	Mean	50.4	51.8	48.1
Engine RPM(rpm)	Max.	4096	4191	3191
	Mean	886	1051	574
Motor Max. RPM(rpm)		9573	10583	5943
Motor Max. Torque(Nm)		145	178	143
Motor Max. Power(kW)		29	35	38
Generator Max. RPM(rpm)		10327	9348	3204
Generator Max. Torque(Nm)		46	44	20
Generator Max. Power(kW)		38	34	7
Battery Voltage(V)	Max.	268	222	394
	Mean	229	215	360
	Min.	185	204	338
Battery Current(A)	Max.	126	130	217
	Mean	0.3	0.7	11
	Min.	-99	-82	-144
SOC(%)	Max.	70.9	84	87
	Mean	63.2	75.1	34
	Min.	55.6	73	21

4 Conclusion

By using the real-time driving monitoring system, we collected and analyzed the driving data of HEV and PHEV in accordance with different driving road conditions like highway, local road

and mountain road, and also different seasonal conditions like summer and winter, and then we obtained results like below.

- In the results of analyzing voltage characteristics of high-voltage battery, driving motor and torque in accordance with driving road conditions like highway, local road and mountain road, the highway with almost no ups and downs of speed has overall narrow distribution while mountain road with lots of stop/go has wide distribution.
- In the results of analyzing the real driving environment of inverter, motor and high-voltage in summer and winter, the outside temperature has big influence on parts temperature during driving.
- Examining the battery characteristics of each vehicle type of xEV in the same driving route, we determine that the differences of SOC distribution are originated from the differences of motor driving method.

Acknowledgments

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