Study on BEV concept design based on data driven approach

Juhyeong Park[1] Jinkyu Moon[2] Junbeom Lee[3] Daeoh Kang[1]

[1]Institute of Vehicle Engineering, Korea, jhp@ivh.co.kr
[2]Institute of Vehicle Engineering, Korea, jkmoon @ivh.co.kr
[2]Institute of Vehicle Engineering, Korea, jblee@ivh.co.kr
[3]Institute of Vehicle Engineering, Korea, bigfive@ivh.co.kr

Abstract

This paper researched the Battery EV concept design based on the data driven model. To determine the performance of BEV in the concept stage, a database was established through market research, and a data driven model was created to derive the target performance and specifications based on the database. To verify the results of the data driven model, the BEV model was generated, and the derived specifications were set. After that, the target performance was confirmed through simulation and detailed specifications were derived.

Keywords : BEV, e-Powertrain

1. Introduction

In the EV development process, there are difficulties in setting and designing system-level performance targets due to the multi-physics characteristics of EVs from a system-level perspective. In addition, the absence of a method for defining module/part target performance to meet system performance and requirements from a module/part level point of view is pointed out as a limitation of the prior art. Against this background, the need to establish a module/parts development strategy and concept considering the xEV system performance was required. In this paper, research was conducted with the goal of developing an xEV system based on system engineering technology. As a research method, based on the results of literature/market research, development concept establishment, model-based architecture, and concept specification design are carried out in the following order. In addition, as the performance of the developed vehicle, the vehicle performance that can be realized with the current e-Powertrain technology was set as a target, and an architecture using only mass-produced parts was implemented.

2. BEV Market Research

In this paper, a BEV database was established through market research. The surveyed vehicles were 37 sedans and 114 SUVs, and the survey items were battery capacity, motor output and torque, mileage, GVW, and wheelbase.

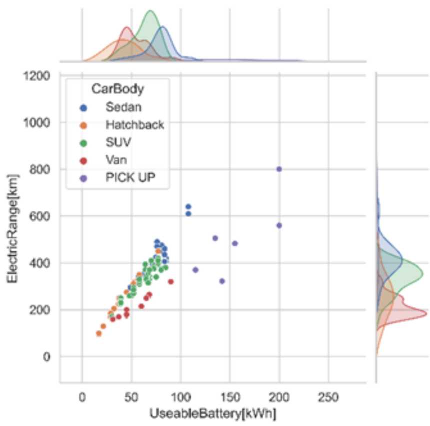

Figure 1. Batter Capacity vs Mileage

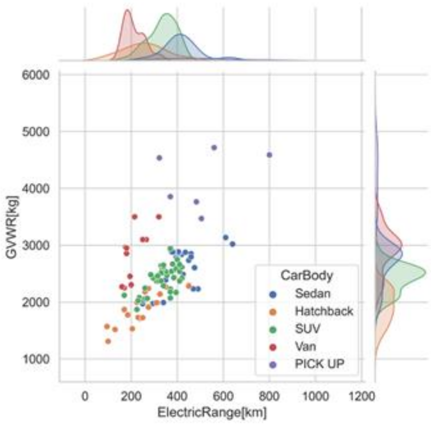

Figure 2. Mileage vs Vehicle Mass

As a result of database analysis, recently mass-produced BEVs tend to be larger and higher in performance. Also, a high correlation between GVW, wheelbase, and battery capacity was confirmed.

3. Data Driven Modeling

To derive the target performance and specifications for the concept stage BEV design, a multi-linear regression model was constructed with the mileage, wheelbase, and vehicle weight as independent variables, battery capacity, motor torque, and motor power as dependent variables. Cross validation technique was used to improve accuracy.

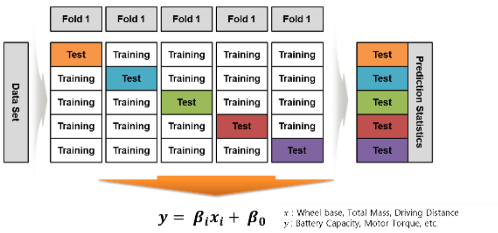

Figure 3. Cross Validation

Through the above process, the following multi-linear regression equations can be found. $Y_{predict}$ is the motor power, motor torque and battery capacity, and obtained the shown in Table 1.

$$Y_{predict} = \alpha_1 * wheelbase + \alpha_2 * Range + \alpha_3 * GVW + \beta$$

$Y_{predict}$	α_1	α_2	α_3	β	R^2
P_{motor}	-9.9e-4	3.6e-1	1.2e+1	-204.9	0.72
T_{motor}	8.7e-3	1.2e-1	4.0e-2	-99.3	0.97
$C_{battery}$	5.9e-1	1.3e-1	1.5e-1	-1607	0.85

Due to the distribution of data in the database, different results are obtained each time the process is performed. To obtain more reliable results, the above process was repeated 10,000 times to collect data, and the average value was set as the final target performance and specifications by confirming the distribution of the collected data. Figure 4 summarizes the entire process for deriving target performance and specifications.

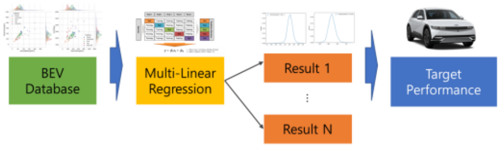

Figure 4. Process to derive target performance and specifications based on database

The design target vehicle is an SUV, with a target mileage of 400 km, wheelbase of 2.9 m, and weight of 3,000 kg. To derive the specifications suitable for the set vehicle, the above-mentioned process was performed, and the data distributions a shown in Figure 5 was obtained.

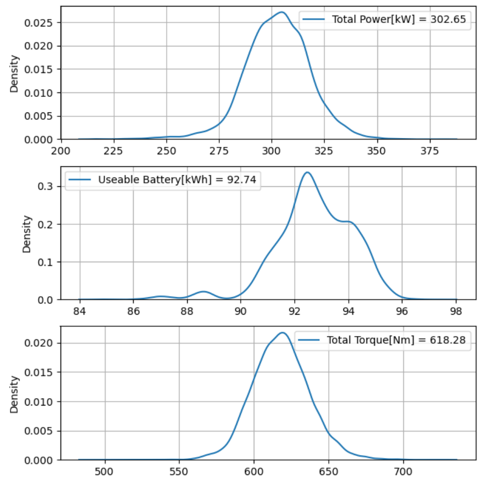

Figure 5. Process progress result data distribution

From the above results, it was found that the motor power required 300kW, a torque of 620Nm, and a battery capacity of 92kWh for the vehicle we intended.

DOI
10.3384/ecp193101

4. Design Validation

To verify the results of obtained from Chapter 3, BEV was modeled and simulated.

4.1. Detail Modeling

BEV modeling was carried out to confirm the target specifications and performance of the BEV concept vehicle derived earlier. The BEV model consists of the Chassis model and the E-Powertrain architecture. The E-Powertrain architecture consists of a battery model and a motor model, and the motor model transmits driving force to the chassis model through Driveline. Chassis model consists of body model, suspension model, and wheel model. For the body, 3,000 kg of GVW was applied as a lumped mass model. For the front/rear suspension, a simple model consisting of force elements such as spring and damper and suspension mass was used, and the Pacejka model was used for the tire model.

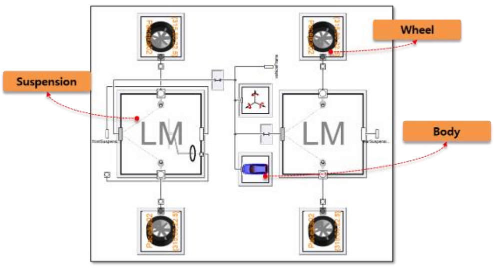

Figure 6. Chassis Model

The e-Powertrain architecture consists of a battery model and a motor model, and three architectures are configured for each drive type. The AWD type of the skateboard platform type using two motors and the FWD/RWD type composed of one motor and driveline were modeled.

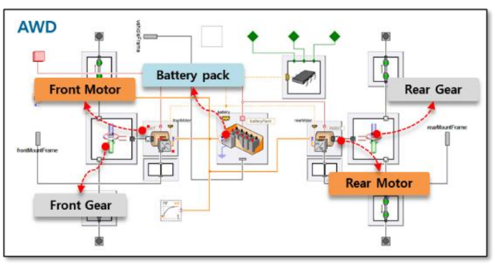

Figure 7. e-Powertrain Model(AWD)

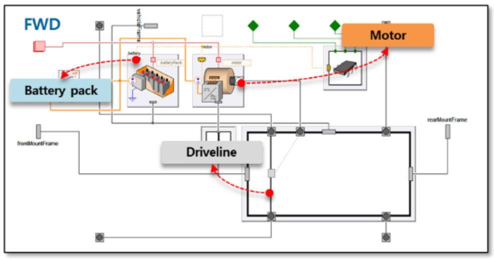

Figure 8. e-Powertrain Model(FWD)

4.2. BEV Simulation

A total of two verification evaluation scenarios for the development concept model were selected. Acceleration performance was confirmed by checking the time to reach the driving speed of 100 kph through the acceleration test, and the total mileage was predicted through the drive cycle driving test, and the final architecture was selected through the e-Powertrain architecture evaluation.

Test	Method
Longitudinal Performance	Full Acceleration Test Measurement of 100kph arrival time
Range Estimation (WLTP Drive Cycle)	Check the battery SOC and calculate the estimated mileage after driving the Cycle

Figure 9. Estimation Scenario

4.2.1. Acceleration Test

The acceleration test was conducted by setting the same motor output and torque for each drive type. As a result of the test, the AWD drive type, which showed the shortest time to reach 100 kph, showed the best acceleration performance. However, the difference in the maximum speed according to the driving method was not significant, and as the maximum speed indicates a high maximum speed of 200 kph or more, there is a need to set and limit an appropriate maximum speed.

4.2.2. Driving Test

For the development concept vehicle model, the total drivable distance was confirmed through the method of driving the WLTP Drive Cycle. The total mileage can be calculated using the formula below.

$$\mathrm{E.M} = \left(\frac{b}{a}\right) * 1\ Cycle\ Distance$$

E.M = Estimated Mileage
a = SOC Reduction
b = Battery Operation Range SOC

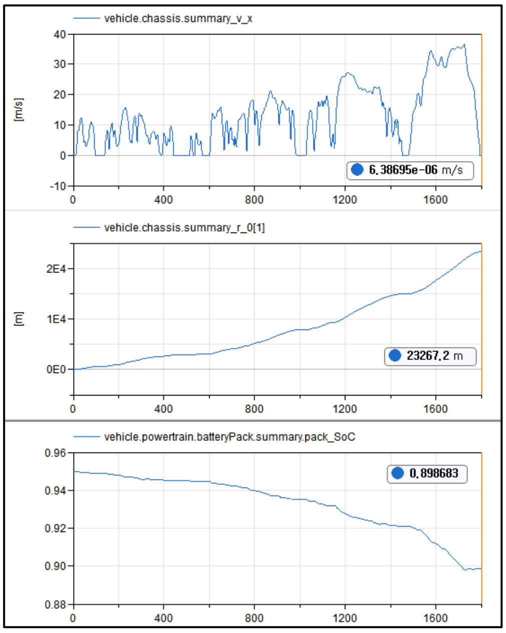

Figure 10. Driving Test Result (WLTP)

5. Conclusion

Various databases were created through market research related to EV development. The target performance for the development concept vehicle model was derived using the created database, and the vehicle performance was predicted through the EV System Architecture model configuration and virtual test environment. As a representative result of the driving performance results, a total mileage of 408 km could be predicted.

Based on the performance prediction results, an optimal EV System Architecture model was established, and through this, the main specifications of the vehicle to be developed were derived.

SUV BEV		
Chassis	Wheelbase	2,900 mm
	GVW	3,000 kg
Motor	Drive Type	AWD (Dual Motor)
	Max Power	300 kW
	Max Torque	610 Nm
	Reduction Ratio	9
Battery	Range	408 km (WLTP)
	Battery Capacity	90 kWh
	Cell Voltage	3.75 V (4.2/2.8V)
	Cell Capacity	80 Ah
	System	3 Parallels, 100 Series

Figure 11. Development Vehicle Specification

References

Micha Lesemann et al., Integrated Architectures for Third Generation Electric Vehicles – First Results of the ELVA Project, Brussels, Belgium, October 26-28, 2011.

Societal scenarios and available technolo-gies for electric vehicle architectures in 2020, Project deliverable, ELVA project consortium, Aachen, 2011

Griffin, J., Batteh, J., and Andreasson, J.: Modeling Vehicle Drivability with Modelica and the Vehicle Dynamics Library 9th International Modelica Conference, Munich, Germany, Sep. 3-5, 2012.

Andreasson, J. and Gäfvert, M.: The VehicleDynamics Library — Overview and Applications 5th International Modelica Conference, Vienna, Austria, pp. 43-51, Sep. 4-5, 2006.

Hirano, Y., Inoue, S., Ota, J.: Model-based Development of Future Small EVs using Modelica 10th International Modelica Conference, Lund, Sweden, Mar. 10-12, 2014.