ABSTRACT

Mode Shift Map and Gear Ratio Optimization of Four-Wheel-Drive Two-Speed Electric Vehicle Considering Rotational Inertia Change

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As environmental regulations are strengthened around the world, electric vehicles (EVs) are expected as an alternative to internal combustion engine vehicles (ICEVs). A typical two-wheel-drive one-speed EV has the advantage of low losses due to its simple configuration, but it largely depends on motor specifications. To resolve this problem, various powertrain systems have been proposed. Among them, a four-wheel-drive two-speed EV using CLAMT (CLuchless Automated Manual Transmission) on the front axle and two motors on each axle, can be expected to improve energy efficiency and dynamic performance with a suitable mode shift map and gear ratio optimization.

The conventional shift map design method only considers the motor efficiency, but the rotational inertia also affects the vehicle performance. Therefore, as a new method of

estimating the motor torque required to satisfy the vehicle acceleration, a mode shift map considering the rotational inertia change could be proposed. Performance evaluation was conducted by developing an EV model consisting of driver, VCU (Vehicle Control Unit), powertrain, brake, vehicle, and battery models based on longitudinal vehicle dynamics. In particular, the flowchart was developed to apply the mode shift map to the VCU model, and the powertrain model mathematically calculates the loss of each component to reflect the effect of multi-speed.

Since the optimal mode shift map depends on the gear ratio combination, the energy efficiency and dynamic performance are maximized by optimizing the gear ratio and the mode shift map simultaneously. Generally, the energy efficiency and dynamic performance have a trade-off relationship with each other, a multi-objective optimization technique is employed and a surrogate model using ANN (Artificial neural network) is developed for efficient optimization. The optimization results showed improvements in energy efficiency and dynamic performance by up to 2.40% and 5.15%, respectively compared to typical two-wheel-drive single-speed EV. Finally, optimal design method of the four-wheel-drive two-speed EV is implemented by MBSE(Model Based System Engineering) and the necessity of considering a rotational inertia change is validated.