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Development of a Loss Measurement Method for Each Component of the Electric Powertrain under In-Vehicle Conditions

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Although losses of individual BEV (Battery Electric Vehicle) powertrain components can be measured on a motor bench, estimating losses under actual operating conditions is difficult due to various vehicle factors. In this study, we developed a method to directly measure the losses of each component (converter, inverter, motor + gear, etc.) of the BEV powertrain under in-vehicle conditions. We report the loss distribution during WLTC (Worldwide Light-duty Test Cycle) mode driving as well as the challenges identified for future work.

Figure 1 shows the wiring diagram of the measurement system developed in this study. For the measurement of the inverter input and output, complex processes were required for the inverter case and high-voltage wiring since the target vehicle has a converter, inverter, motor, and gear integrated into a single structure. In addition, the power meter selection and settings were optimized considering high-frequency characteristics and phase correction because the inverter output contains many high harmonics. For the measurement of the motor+gear output, a strain-gauge-type torque sensor was attached to the drive shaft and calibrated using the actual torque. Furthermore, to measure the rotational speed and avoid the influence of tire deformation, an encoder mounted on the wheel was used instead of the rotational speed measured by the dynamometer.

If vehicle driving data alone is used, losses inside the battery cannot be considered. Therefore, the same test sequence as the WLTP (Worldwide harmonized Light vehicles Test Procedure) was adopted. In this method, after conditioning and full charge, the WLTC mode is driven until the battery is depleted, and the energy consumption is determined from the recharged energy and driving data.

To visualize the contribution of losses in each unit on energy consumption, Figure 2 shows a detailed breakdown of individual energy losses contributing to the total loss during WLTC mode driving. From this graph, it is possible to identify components with large losses and to confirm the priority for high efficiency and the influence of each component's loss on energy consumption.

Moreover, if the obtained data is organized by torque and rotational speed, it is possible to identify the driving areas in which each unit exhibits higher losses. Figure 3 shows the driven area. Data were summed for each small area (10 Nm, 500 rpm), and the loss ratio relative to the total loss of each unit is shown in Figure 4. Figure 4 shows the loss map of the motor+gear. It can be seen that the motor+gear losses are higher in the range of 6000 - 10000 rpm and 0 - 50 Nm. Since this area is dominated by iron and mechanical losses, iron losses can be reduced by improving the electrical resistivity of materials or by using thinner sheets. Thus, specific guidelines for powertrain development can be obtained.

In conclusion, we developed a method to measure the losses of each unit in an BEV powertrain under in-vehicle conditions. This enables the identification of components or driving areas with high losses, serving as guidelines for powertrain and component development. Due to the absence of clear constraints regarding the accuracy, measurement instruments for torque are selected for practical reasons. Therefore, optimizing the selection of measurement instruments for torque and calibrating their uncertainties are future challenges.

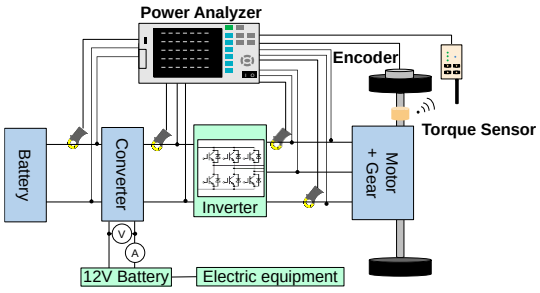

Fig. 1 Wiring Diagram while Driving

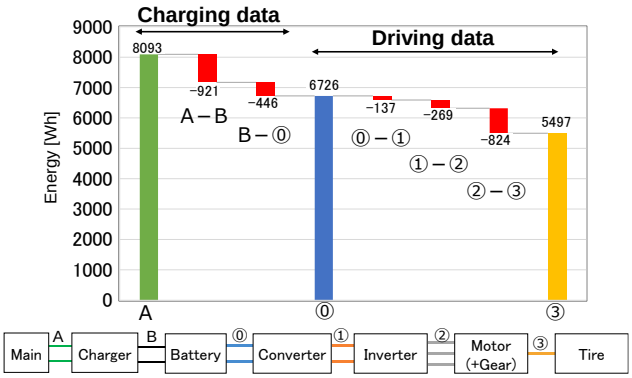

Fig. 2 Detailed Breakdown of Individual Energy Losses Contributing to the Total Loss

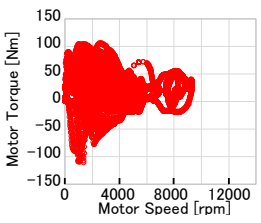

Fig. 3 Driving Data

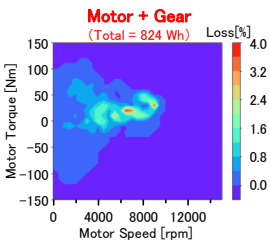

Fig. 4 Energy Loss Map