別紙４

報告番号	※　　　　　第　　　　　号

主　論　文　の　要　旨

論 文 題 目　Traction Force-Speed Based Modelling for Hybrid Vehicle Energy Consumption

（ハイブリッド車のエネルギー消費計算のための駆動力・車速ベースモデルに関する研究）

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論　文　内　容　の　要　旨

According to the coming of rapid hybrid-vehicles penetration, it is necessary to prepare effective tools to help projecting the directions of future developments on on-road transportation fuel consumption and greenhouse gas emissions. Thus, this study attempts to develop hybrid vehicles' energy consumption model for transportation research applications. I also present an inclusive modeling methodology which consisted of hybrid vehicles experiment, data acquisition, data processing, power-split hybrid powertrain operation control analysis, and the hybrid vehicles' energy consumption modeling. Based on the hybrid powertrain operation characteristics examined in this study, a microscopic analytical-empirical energy-consumption model called Traction Force-Speed based Energy Consumption Model (TFS model) is proposed.

Real-world experiments, private circuit experiments, and chassis dynamometer experiments are conducted to analyze and compare the advantages and disadvantages. According to the finding, real-world experiments are the most suitable approach for vehicles' fuel-consumption data acquisition. Meanwhile, chassis dynamometer experiments could provide the ability to sweep the powertrain operation points through all the regions. Thus, chassis dynamometer experiments are highly recommended for the data acquisition for the powertrain operation characteristics.

Next, this study investigates and validated the operation characteristics by applying the dataset to improve the powertrain operation models to become more realistic by using the Prius3 CRUISE AVL simulation platform. To obtain the requisite parameters, the power-flow path inside the power-split configuration is analyzed. Then, the powertrain's dynamic equations were derived and adopted in the parameter estimations and map calibrations.

By applying the calibrated maps and models into the simulation, the fuel consumption and powertrain operation are significantly improved to be more realistic. According to the analysis, it indicated that the hybrid powertrain operated in multi-operation modes. The transition of the modes could be simplified and expressed by boundaries specified by vehicle speed and driving force as the X-Y axis. In addition, the boundaries also varies depending on the instantaneous available battery power.

One of the most important modeling processes is to estimate vehicle driving power. Firstly, a practical and cost-efficient approach to recalibrate coefficients of the vehicle-driving-power estimation equation for a specific vehicle model or fleet is proposed. This study implements the assessable CAN dataset to estimate the powertrain's total driving power via the powertrain's dynamic equation derived in the previous process. The coefficients in the vehicle-driving-power-estimation equation are calibrated with the powertrain's total driving power by applying stepwise multiple regression method. The results show that the calibrated equation significantly improved the driving power estimation compared to the conventional VSP (Jiménez et al., 1999). Particularly under heavy load driving (above 50kW) and high-speed driving (above 80km/h), the proposed method substantially suppressed the prediction error by having the coefficient improved from 0.79 to 0.96.

Then, the TFS model is constructed based on the relationships between the vehicle speed and the average fuel consumption rate at specified traction force intervals. The trend of the vehicle speed and the fuel consumption rate monotonically increased as the traction force became more intense. The prediction results show that the TFS method efficiently reduced the error by 57% down to 23% compared to the conventional VSP energy consumption modeling method.

Furthermore, this study also explores hybrid vehicle fuel consumption characteristics in a different aspect. The objective of the project was to investigate the impact of winter tires and summer tires on hybrid vehicle fuel consumption. This study suggests a new parameter called instantaneous hybrid powertrain efficiency that incorporated the efficiency of the electric system and the engine system. The results show that this parameter provided the capability to analyze and visualize delicate factors that impacted the fuel consumption of the hybrid powertrains compared to fuel economy-oriented parameters, such as L/100km or km/L. Finally, the most significant remark is found that the summer tires tend to allow the powertrain system to operate at higher efficiency regions more frequently than the winter tires, particularly during deceleration under EV and HV regenerative braking and typical hybrid driving.