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Research article

# Study on driver model for hybrid truck based on driving simulator experimental results☆

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ABSTRACT

In this paper, a proposed car-following driver model taking into account some features of both the compensatory and anticipatory model representing the human pedal operation has been verified by driving simulator experiments with several real drivers. The comparison between computer simulations performed by determined model parameters with the experimental results confirm the correctness of this mathematical driver model and identified model parameters. Then the driver model is joined to a hybrid vehicle dynamics model and the moderate car following maneuver simulations with various driver parameters are conducted to investigate influences of driver parameters on vehicle dynamics response and fuel economy. Finally, major driver parameters involved in the longitudinal control of drivers are clarified.


## 1. Introduction

The rate of fuel consumption by vehicles is usually evaluated with the standard driving pattern test. However, the fuel consumption in an ordinary traffic flow is greatly affected by the controlling actions of the driver. A number of studies have been carried out to examine and quantify the influence of driving characteristics, and they revealed that those elements of driver behavior related to gear shifting, speed choice and acceleration and deceleration have the greatest influence on fuel consumed [1,2]. Other studies deal with a model of optimal driving strategies to apply for assessment of e-co driving rule [3] or to design a fuel efficiency support tool [4]. If the fuel consumption deviates from this optimum, the support tool advises the driver on how to change his driver behavior in order to optimize fuel economy. However, the aforementioned studies analyze driver behavior in descriptive manners that do not address the driver behavior in a systematic driver-vehicle system. Therefore, it is important to analyze the fuel consumption in traffic flow from the viewpoint of driver-vehicle system control engineering. Moreover, in order to predict how different groups of drivers might respond and, therefore, to reveal how control process of the driver-vehicle system affects the fuel economy of a vehicle in its design stage, a reliable simulation of a large number of different driver behavior characteristics will be necessary from time to time. Among the three system components: driver–vehicle–environment, vehicle is the most thoroughly studied and mathematically described element. Currently, the environment is also being described in more detail (tire adhesion coefficient, road structure, etc.). A very strong disproportion is visible here because often the driver model here is more like a ‘driver robot’ than a ‘test driver’ when his task is simply to keep track of given speed profiles [5]. As driver behavior is one of the main causes of difference in fuel economy, a simulation conducted without taking into account the driver's actions cannot be fully reliable. Yet, this is a reason for wanting to have models of the driving task that are not mere descriptions of tasks performed by the driver or of influences on driver behavior but which are more generic representations of vehicle control process. Another reason is for future use as an intelligent co-driver on board the vehicle, able to provide feedback to the human driver and also to fine-tune the operation of in-vehicle systems to the needs and preferences of each particular driver.

In this study, we paid attention to the drivers' operation of the throttle in the back and the longitudinal control and then considered a control structure. A human pedal operation model for the car following situation taking into account some features of both the compensatory and anticipatory model has been proposed. The form of the model is intended to be sufficiently flexible for it to be developed to consider factors affecting variability in longitudinal dynamics control and fuel economy performance of drivers. The driver model parameters will be obtained through simulator experiments with several real drivers. Subsequently, each particular driver model will join in closed-loop of driver-vehicle system simulations and compare with experiment data to validate the driver model. It demonstrates that the driver model is adequate for the analysis of fuel economy as well as longitudinal dynamics control process of the driver-hybrid truck system and clarifies

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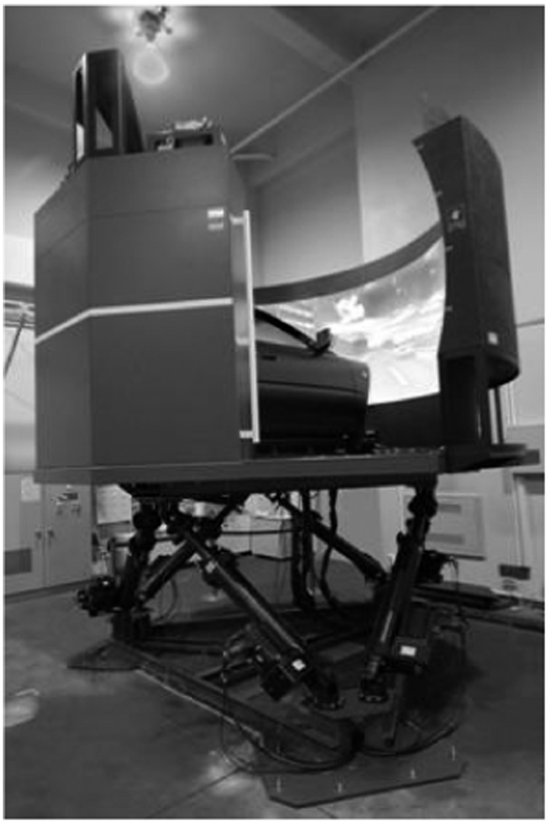

**Fig. 1.** Driving simulator.

longitudinal control characteristics which affect the operation of a hybrid vehicle and fuel economy.

## 2. Driving simulator experiments

### *2.1. Configuration of driving simulator*

This driving simulator is composed of a hexapod motion generator, a cabin, a front view road generator system, an audio system, and a host computer for controlling motion system and computing vehicle motion in real time as shown in Fig. 1.

The motion system composed by six actuators can generate six-degree-of-freedom motions and their accelerations to the driver.

The host computer is equipped with a DSP board, and we can embed the algorism of a hybrid control system on the driving simulator.

The vehicle dynamics model is a full vehicle model considering the tire forces for each four wheels, the load shift caused by rolling of the body, and so on. The vehicle model parameters are shown in Table 1.

These functions of the driving simulator enable the driver of this simulator to obtain a real driving feel and operate it in the same way as a real vehicle.

**Table 1**
Vehicle model parameters.

| Definition | HEV | unit |
|---|---|---|
| Vehicle mass | 4500 | kg |
| Wheel base | 2.525 | m |
| Distance from front axle to gravity center | 1.01 | m |
| Height of gravity center | 1.3 | m |
| Tread | 1.50 | m |

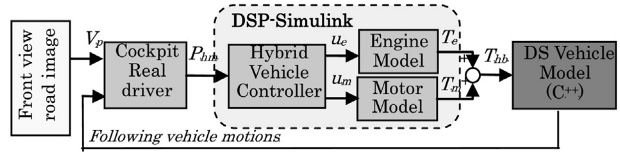


**Fig. 2.** Driver-Hybrid truck system.

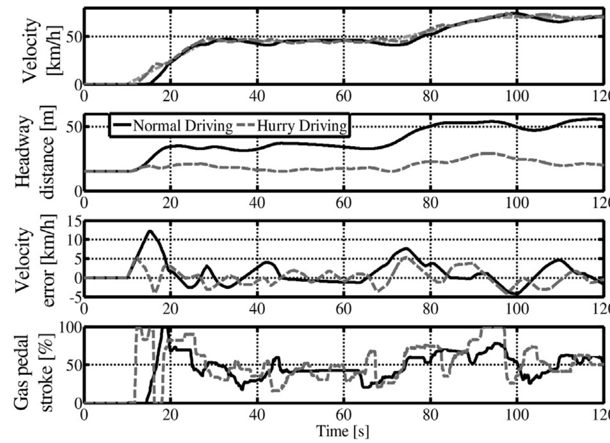


**Fig. 3.** Comparison of hurry and normal driving experimental results.

### *2.2. Driving simulator experiments*

Driving simulator experiments are carried out to study the effects of human longitudinal control on the driver-vehicle system in closed-loop as shown in Fig. 2.

Although naturalistic driver behavior consists of various individual traffic situations such as car following, cruising, stopping, starting and braking, we started this research focused on the car following situation. The preceding vehicle accelerates from 0 km/h with a moderate acceleration of 0.68 m/s2 and cruises at a constant speed of 45 km/h and then accelerates with an acceleration of 0.3 m/s2 to a constant speed of 70 km/h. These accelerations are referred from the 10–15 mode test. This study is limited to a small sample size and homogeneous driver. Five well-trained male drivers in their 20′s and 30′s are chosen to conduct experiments in both normal driving and hurry driving situations. The hurry driver tends to keep the headway distance short.

## 3. Driver-vehicle in closed-loop analysis

As an example, time history of vehicle movements and human accelerator pedal operation are plotted in Fig. 3 for comparing the driver-vehicle system response in hurry driving and normal driving situations.

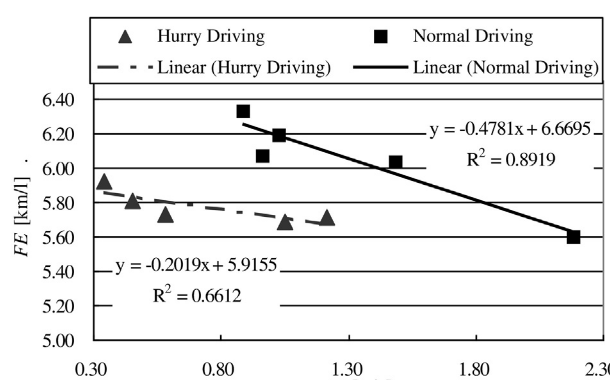


**Fig. 4.** The relationship between averaged velocity error and fuel economy.

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