Comparative measurements of the eco-driving effect between electric and internal combustion engine vehicles

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Abstract
Not only ICEV user but also EV users have interest in eco-driving. So, in this study, quantitative evaluation of eco-driving effect for EV was conducted using chassis dynamometer with new developed “Eco-driving test mode”. They were extracted from seventy two real-world driving data collected at the Eco-driving test-ride event. And they had four speed patterns which had same travel distance of 5.2 km and wide range of kinematic running energy. Three ICEVs, one HEV and two EVs were tested. The results showed that good linear relationships were found between kinematic running energy and fuel consumption rate for all 6 tested vehicles. Thus, eco-driving with low kinematic running energy by observing speed limit and constant speed was effective to not only ICE but also HEV and EV. The eco-driving effects from averaged drive as usual to averaged eco-driving in the eco-driving test-ride were estimated. And the effects of 660cc CTV ICEV, 1,300cc CVT ICEV, 1,800cc 4AT ICEV, 1,500cc HEV, EV type A and EV type B were 12.0%, 12.2%, 10.9%, 12.6%, 18.4% and 11.7% respectively. And the results indicated that EV had higher potential of eco-driving effect than ICEV if EV could maintain high energy conversion efficiency with various driving situations.

Keywords: BEV, HEV, energy consumption, eco-driving, chassis dynamometer

1 Introduction
Mainly in the Europe, eco-driving was popular as global warming measure in transport sector. For example, “ecodriving.org” reported that eco-driving save fuel 5-15% in the long time, and listed 5 “Golden Rules of Eco-driving” : 1. anticipate traffic flow, 2. maintain a steady speed at low RPM, 3. shift up early, 4. check tyre pressures frequently at least once a month and before driving at high speed, 5. consider any extra energy required costs fuel and money [1]. In Japan, 10 eco-driving tips are listed and especially “go easy on the acceleration pedal” is strongly recommended [2]. There are some differences between European and Japanese tips. But also in Japan, there are many reports about effectiveness of eco-driving (for examples [3]-[5]). Kato and Kobayashi [5] reported that eco-driving in test-ride event saved 11.6 % of fuel consumption and its major factor was the decrease of kinematical running energy by observing speed limit and constant speed. On the other hand, EV users have interest in eco-driving from the aspect of preserving the travel
distance of EV [6]. However, the discussion and quantitative evaluation is rare whether eco-driving methods for internal combustion engine vehicles are valid for the EV. Therefore, this study conducted comparative measurements of the eco-driving effect between electric and internal combustion engine vehicles using chassis dynamometer.

2 Test Method

2.1 Development of Eco-driving Test Mode

“Eco-driving test mode” was developed to evaluate the relationship between the kinematic running energy and fuel (or electric) consumption rate. Figure 1 shows 4 speed patterns of “eco-driving test mode”. And Table 1 shows specifications of test mode. The kinematic running energy of “ECO-S” is lowest and become higher in order of “ECO-A”, “ECO-B” and “ECO-C”. These 4 speed patterns were extracted from 72 real-world driving data collected at the Eco-driving test-ride event held in Tsukuba, Japan [5]. The travel distance of each speed pattern was 5.2 km. Figure 2 shows the relationship between kinematic running energy and fuel consumption rate in the eco-driving test-ride event. 72 driving data which included both speed patterns driving as usual and eco-driving were collected. The test subjects were instructed eco-driving by observing speed limit and constant speed. As a result, eco-driving decreased 15.5% of kinematic running energy and 11.6% of fuel consumption. Type of vehicle driven in eco-driving test-ride event was a ICEV equipped 1,300cc engine and CVT.

Table 1: Specifications of Eco-driving Test Mode

<table>
<thead>
<tr>
<th>Travel time (sec)</th>
<th>Eco-S</th>
<th>Eco-A</th>
<th>Eco-B</th>
<th>Eco-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time ratio</td>
<td>idle</td>
<td>Run</td>
<td>Acc</td>
<td>Dec</td>
</tr>
<tr>
<td>Max speed (km/h)</td>
<td>56</td>
<td>64</td>
<td>66</td>
<td>80</td>
</tr>
</tbody>
</table>

Figure 1: Speed Patterns of Eco-driving Test Mode

Figure 2: Relationship between Kinematic Running Energy and Fuel consumption Rate at the Eco-driving Test-ride event (real-world driving data)

2.2 Chassis dynamometer Test

Three ICEVs, one HEV and two EVs were tested using chassis dynamometer. The engine displacements of ICEVs were 660cc, 1,300cc and 1,800cc, and the one of HEV was 1,500cc. 660cc and 1,300cc ICEVs were equipped CVT. 1,800cc ICEV was equipped 4 automatic transmission. Both two EVs were small passenger cars which called “kei-car” in Japan. One EV was front-wheel drive vehicle (called “EV type A” in this paper), another was rear-wheel drive vehicle (called “EV
type B” in this paper). EV type A was not in the market yet.

3 Results and Discussion

3.1 Fuel Consumption (electric energy consumption)

Figure3, Figure4 and Figure5 show the test results of ICEVs. Figure6 shows the results of HEV. Figure7 and Figure8 show the test results of EVs. Each figure has 4 circle-markers which mean the fuel (electric energy) consumption of ECO-S, ECO-A, ECO-B and ECO-C. With all of 6 types of tested vehicles, good linear relationships were found between kinematic running energy and fuel consumption rate. These results indicate that eco-driving with low kinematic running energy by observing speed limit and constant speed was effective to not only ICE but also HEV and EV.

3.2 Estimation of Eco-driving Effect

The eco-driving effects of each vehicle were estimated using regression line. The reduction rates of fuel consumptions or electric consumptions from averaged drive as usual to averaged eco-driving in the eco-driving test-ride were calculated. Arrow lines in each figure show the eco-driving effects. The effects of 660cc CVT ICEV, 1,300cc CVT ICEV, 1,800cc 4AT ICEV, 1,500cc HEV, EV type A and EV typeB were 12.0%, 12.2%, 10.9%, 12.6%, 18.4% and 11.7% respectively.

3.3 Energy Efficiency

Four square-markers in each figure show the Energy Efficiency of ECO-S, ECO-A, ECO-B and ECO-C. The energy efficiency of ICEVs and HEV decreased with eco-driving. These results indicated that the areas of engine with low energy conversion efficiency were used in eco-driving with low running energy. EV type A had a higher eco-driving effect than other tested vehicles because it had high energy efficiency with wide range of running energy. This result indicated that EV had higher potential of eco-driving effect than ICEV if EV could maintain high energy conversion efficiency with various driving situations.
4 Conclusion

Comparative measurements of the eco-driving effect between electric and internal combustion engine vehicles were conducted using chassis dynamometer. Eco-driving with low kinematic running energy by observing speed limit and constant speed was effective to not only ICE but also HEV and EV. The eco-driving effects of 660cc CTV ICEV, 1,300cc CVT ICEV, 1,800cc 4AT ICEV, 1,500cc HEV, EV type A and EV type B were 12.0%, 12.2%, 10.9%, 12.6%, 18.4% and 11.7% respectively. EV had higher potential of eco-driving effect than ICEV if EV could maintain high energy conversion efficiency with various driving situations.

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References


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