EVS27
Barcelona, Spain, November 17-20, 2013

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

Hideki Kato[1], Ryosuke Ando[2], Yoshinori Kondo[3], Tsutomu Suzuki[4], Keisuke Matsuhashi[5], Shinji Kobayashi[6]

[1,2]Toyota Transportation Research Institute, 1-1, Wakamiya-cho, Toyota, Aichi, 471-0026 Japan, kato@ttri.or.jp
[3,5,6]National Institute for Environmental Studies, 16-2, Onogawa, Tsukuba, Ibaraki 305-8506 Japan
[4]Tsukuba University, 1-1-1, Tennoudai, Tsukuba, Ibaraki, 305-8573 Japan

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. Figure1 shows 4 speed patterns of "eco-driving test mode". And Table1 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. Figure2 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.

Table1: Specifications of Eco-driving Test Mode

		Eco-S	Eco-A	Eco-B	Eco-C
Travel time (sec)		648	628	627	612
Time ratio	idle	14%	20%	26%	28%
	Run	40%	35%	29%	20%
	Acc	23%	24%	26%	24%
	Dec	23%	20%	18%	29%
Max speed (km/h)		56	64	66	80

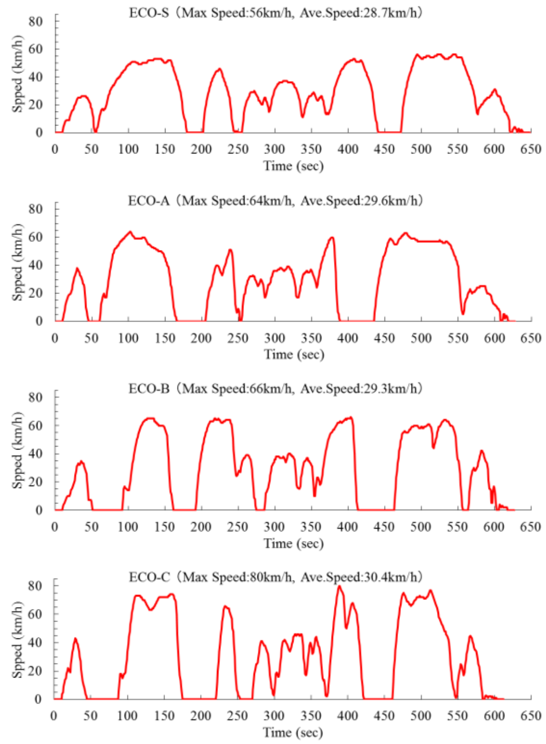

Figure1: Speed Patterns of Eco-driving Test Mode

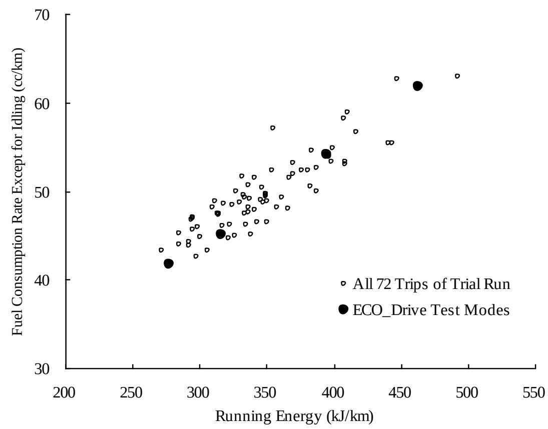

Figure2: Relationship between Kinematic Running Energy and Fuel consumption Rate at the Eco-driving Test-ride event (real-world driving data)

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 CTV 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.

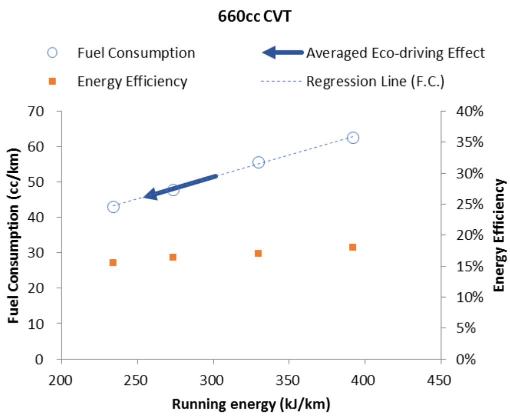

Figure3: Test Results of ICEV (660cc CVT)

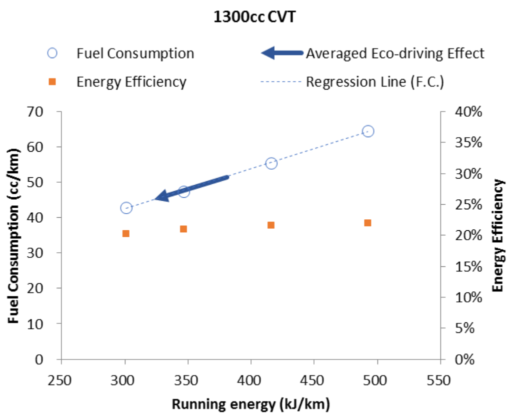

Figure4: Test Results of ICEV (1300cc CVT)

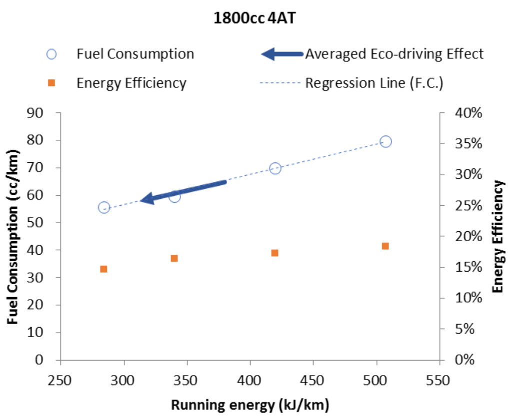

Figure5: Test Results of ICEV (1800cc 4AT)

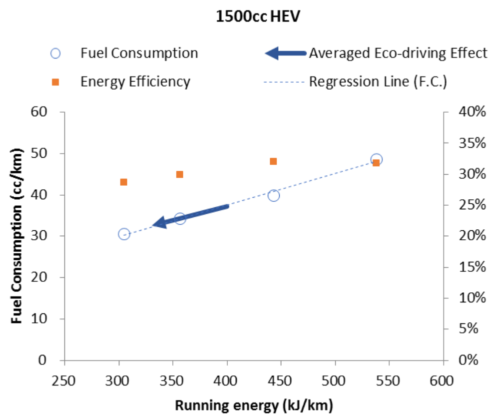

Figure6: Test Results of HEV (1500cc)

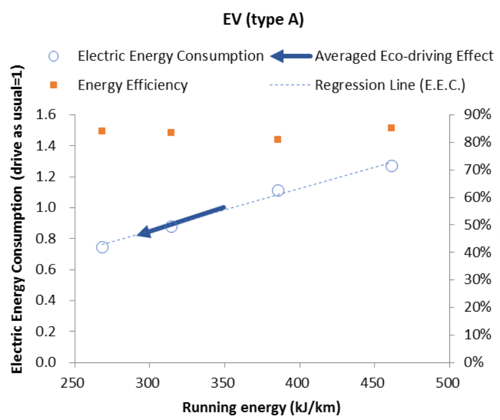

Figure7: Test Results of EV (Type A)

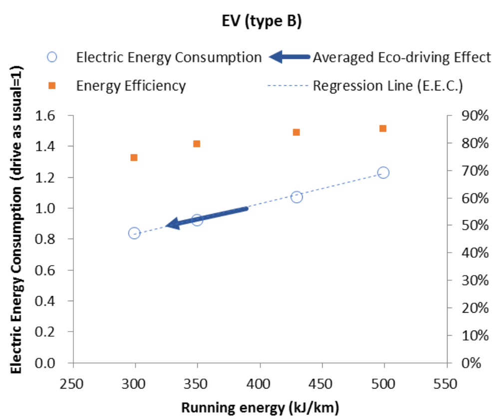

Figure8: Test Results of EV (Type B)

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.

Acknowledgments

This work was supported by JSPS KAKENHI Grant Number 24310116.

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Authors

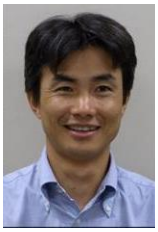
Dr. Hideki Kato is a Senior Research Engineer at Toyota Transportation Research Institute (TTRI). He received the B., M. and D. engineering degrees from Hokkaido University. He joined TTRI in 2011 after around five-year experiences in NIES. His principal areas are environmental, automotive and traffic engineering. Especially, his concerns are eco-driving issues.

Dr. Ryosuke Ando has been Chief Research Engineer and Director of Research Department at TTRI since 2004. He received the B. engineering degree from Tsinghua University, and the M. and D. engineering degrees from Nagoya University. His major fields are traffic and transportation planning and engineering, urban planning and ITS.

Dr. Yoshinori Kondo is a Senior Researcher at National Institute for Environmental Studies, Japan (NIES). He received the B., M., and D. engineering degrees from Kobe University. He joined NIES in 1998 and currently his principal concerns are electric or human-powered mobility, public transportation, and human health issues.

Dr. Tsutomu Suzuki is a Professor in the Department of Risk Engineering at the Graduate School of Systems and Information Engineering, University of Tsukuba (since 2005). He earned a doctoral degree (engineering) from the University of Tokyo in 1995. His research topics range from location analysis, spatial analysis, and urban structure to transportation modeling.

Dr. Shinji Kobayashi is a Visiting Researcher in Center for Regional Environmental Research at National Institute for Environmental Studies, Japan (NIES). Earlier his research field was a diesel engine issue. Currently his principal concerns are environmental impacts of vehicle exhaust and global warming countermeasure.



Dr. Keisuke Matsuhashi is a senior researcher in Center for Social and Environmental Systems at National Institute for Environmental Studies, Japan (NIES). He received the B., M. and D. engineering degrees from Tokyo University. He joined NIES in 1996. his principal concerns are low-carbon society, sustainable transportation and air pollution.