EVS24
Stavanger, Norway, May 13-16, 2009

EV Range Extender: Better Mileage Than Plug-in Hybrid?

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Abstract

This paper shows that EV range-extender (RXT) will provide better mileage than the plug-in hybrid (PHEV) when a model usage of vehicle is applied. The model is assumed to be: 30 km (6 days a week), 100 km (1 day a week). A RXT system was made for this evaluation using a pure EV and an electric generator on a trail. Japan 10-15 mode is used for the calculation. The result shows that 35.4 kWh/weeks is obtained for RXT, while 36.5 kWh/week for PHEV. This would be the first evaluation of RXT based on fuel economy.

Keywords: HEV, RXT, PHEV, fuel economy, electric vehicles

1 Introduction

The purpose of this research is to evaluate the system of electric vehicles numerically by comparing the mileage performances. HEV is becoming popular in the world and Toyota sold more than one million HEV's totally in 2007. HEV is aimed to reduced fuel consumption. Recently PHEV has become popular in research to minimize the use of gasoline. For short range driving, PHEV is regarded as a pure EV. PHEV, however, always carries heavy ICE systems. RXT is developed to find a more efficient system to use for car performance. RXT carries ICE only in the case of long distance use. This system is produced and it is evaluated to show the mileage performance of RXT in comparison with PHEV system.

2 Production of RXT System

A pure EV is made for the evaluation. Figure 1 shows an AC motor and AT1200 gear box used for the EV. Figure 2 shows a view of the EV. The specifications of the EV Civic is shown in Table 1. Table 2 shows the performance of the EV used for the evaluation.

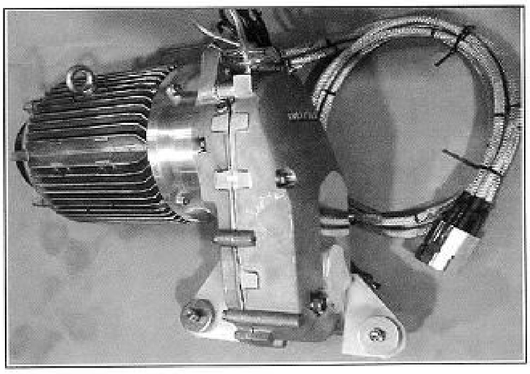

Figure 1. A photograph of the Solectria Motor

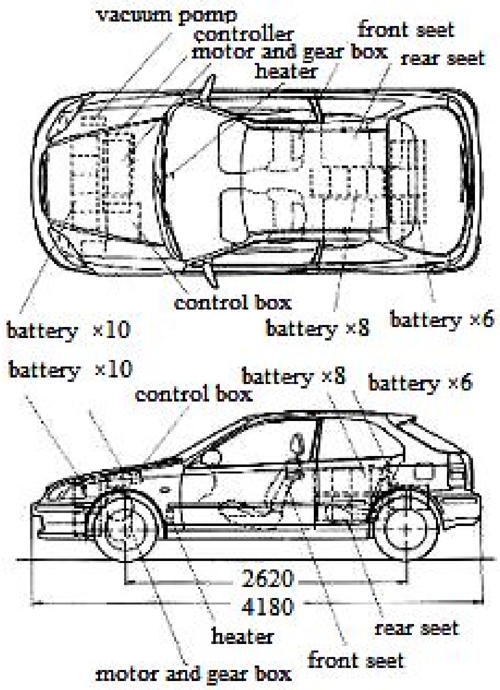

Figure 2.. EV Civic configuration

Table 1. Specification of EV Civic

Item	HONDA Civic('95)	EV Civic
Engine Capacity or Output power	1.493[liter]	67[kW]
Length [m]	4.180	
Width [m]	1.695	
Height [m]	1.375	
Wheel-base [m]	2.620	
Passengers	5	
Total weight [kg]	1275	4
Tire size	175/70R13 82S	1538
Rotating radius [m]	5	

Table 2. Specification of the EV

Item	Specification
Motor	SOLECTRIA 3phase induction motor
Output power	18kW, Max. 67kW(DC 288V)
Max torque	140Nm
Revolution	0～12000rpm(Reverse 0～3000rpm)
Motor efficiency	Over 90%
Controller	SOLECTRIA UMOC 78kW
Controller Efficiency	Over 98.5%
Gear Box	SOLECTRIA 10:1
Battery	12V58Ah Lead-acid battery 24series(288V)

Figure 3 shows the configuration of the generator trailer and a photograph. Table 3 shows the performance of the generator trailer used for the evaluation.

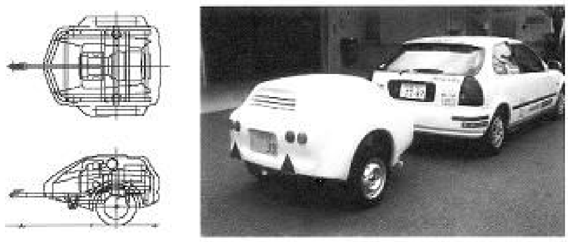

Figure 3. Configuration of the generator trailer and the photograph with the EV

Table 3. Specification of the generator trailer

Item	Specification
Length[m]	2.130
Width[m]	1.380
High[m]	1.040
Mass[kg]	375
Output voltage[V]	DC350
Max power[kW]	15
Net power[kW]	11

3 Evaluation Of RXT System

A comparison between RXT and PHEV are made using the following 3 values:

- Required power to the running velocity of vehicles.
- Total energy required to run one cycle of Japan 10-15 mode velocity profile, average energy per 1 km based on Japan 10-15 mode.
- Required total energy to run a given weekly usage pattern of RXT and PHEV

For the comparison, vehicle parameters are obtained by the following method.

The vehicle parameters of RXT are deduced by experimental test. The value of Cd is 1.49 (without generator trailer), while Cd is 1.73 with generator trailer. The rolling factors of RXT are 0.0074 and 0.0095 without and with generator trailer respectively.

The vehicle parameters of PHEV are obtained by calculation. The value of Cd is 1.49, and the rolling factors of PHEV is

0.0074. The total weight of PHEV is 1888 kg because the generator weight of 350 kg is added to the RXT without the generator trailer. These parameters are listed in Table 4.

Table 4. Specification of vehicles for the evaluation

		Mass [kg]	μ	CdS
RXT	Generator trailer	1913	0.0095	1.73
RXT	No Generator trailer (EV mode)	1538	0.0074	1.49
PHEV		1888	0.0074	1.49

The method to obtain the required energy to run is explained. It is assumed that the charging loss by the generator is neglected. The transmission loss from the motor to the wheel is also neglected for the evaluation of the required energy. The energy for the comparison is calculated based on the required energy to run against the rolling resistance, drag force and the acceleration resistance.

3.1 Relations between the velocity of the vehicles and the required power

Figure 4 shows the required power, P, to the vehicle velocity for the pure EV mode of RXT, RXT with the generator, and the PHEV. RXT with the generator trailer needs higher power because of the large value of the rolling resistance and the drag resistance.

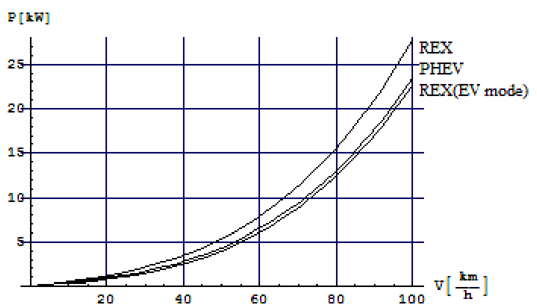

Figure 4. Required power vs. velocity for the different kinds of vehicles

3.2 Required energy based on Japan 10-15 mode

Table 5 shows the calculated required total energy to run one cycle of Japan 10-15 mode and the running distance per 1 kWh. The result shows that pure EV mode of RXT has the best mileage, while RXT with the generator trailer has the worst mileage.

Table 5. Required energy based on 10-15mode running

		Energy required for one 10-15 mode [Wh]	Running distance for 1kWh [km/kWh]
RXT	Generator trailer	770	5.30
RXT	No Generator trailer(EV mode)	595	6.86
PHEV		690	5.91

3.3 Required energy for the weekly usage pattern

To evaluate the best mileage of the 3 vehicles used, the parameter of γ is used. The value of γ is determined as the ratio of the total usage distance of EV-mode RXT to the total distance of RXT with the generator trailer. The bigger value of γ means the running distance of EV mode is longer than the RXT mode. Figure 5 shows the calculated running mileage [km/kWh] to the value γ.

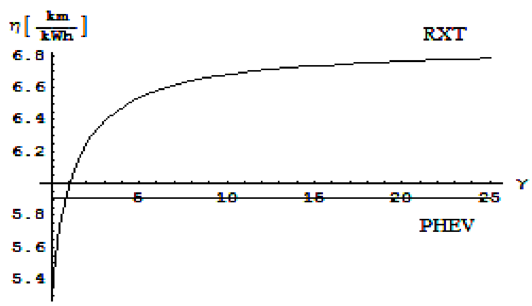

Figure 5: Ratio of long running to short running vs. required energy

This result shows that RXT has better mileage [km/kWh] than PHEV if γ is greater

than 0.83. It is assumed that EV mode can be used when the running distance is less than 110 km.
For example, a weekly usage pattern is taken into account. The pattern assumed here is that the running distance per day is 30 km for 6 days a week as a pure EV mode without the generator trailer. Once a week, the running distance becomes 200 km as RXT with the generator trailer mode. All running patterns are assumed to be based on Japan 10-15 mode.
The resulted mileage is listed in Table 5. The weekly required energy for RXT is 64.0 kWh, while it is 64/3 kWh for PHEV. The value of γ is 0.9. If the daily running distance is large and there are few chances to take a long distance trip, the value of γ is large and the mileage of RXT becomes better than PHEV. The good mileage of RXT becomes saturated to 6.86 km/kWh if the value of γ is higher than 20. It is concluded that the PHEV is not always better than the pure EV as well as RXT. For the small value of γ, this result shows that the mileage is not good for the pure EV. RXT has a strong advantage, however, to the pure EV because of the long distance running ability. A better solution to the possible EV systems for different driving patterns should be considered.

4 Conclusion

This experimental result shows that the RXT would have a better mileage than PHEV for a model velocity pattern. More generalized research will provide the performance of RXT qualitatively.

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