Innovative Renewable Energy Solutions for Hydrogen Vehicles

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[Excerpt]
This paper presents a study of innovative vehicle design for fuel cell vehicles. Surveys on latest technologies of battery, fuel cells, regenerative brake and photovoltaics, suggested three types of fuel cell vehicle design, FCV (simple fuel cell vehicle), HFCV (hybrid fuel cell vehicle with regenerative brake), and HFCVP (hybrid fuel cell vehicle with rooftop photovoltaics) The driving powers of the vehicles are estimated by official 10-15 mode driving test data. Dynamic simulations of HFCVP, using one-minute solar radiation data of several cities in Japan, show the hydrogen consumption for three driving patterns a year and for the different capacities of battery and hydrogen sub tank. The total cost of three types of fuel cell vehicles are estimated by combining cost of fuel cell vehicles and hydrogen fuel. The results show the hydrogen consumption and CO2 emission of HFCV is nearly 20% less and that of HFCVP is nearly 40% less than hydrogen consumption of simple FCV.

Driving Power of Vehicles

To evaluate energy efficiency of vehicles, it is important to estimate driving power of vehicles. The 10-15 mode driving test is usually used for the official fuel economy test in Japan. This driving test defines the velocities at each second for 660 seconds (11 minutes) for the driving distance 4.16 km. The drive power is defined by the driving equation as follows, and the numbers are for medium sized passenger car.

$$Mr\ dV/dt = D - 1/2\ ro\ As\ Cd\ V^2 - r\ M\ g - B$$

M: Mass of vehicle + mass of passengers (2 persons) =1260+55x2=1370kg
Mr: Mass of vehicle + rotational equivalent mass=1748kg
g: Gravity constant (9.8m/sec2) D: Driving force (Newton) B: Brake force (Newton)
ro: Air density (1.2kg/m3) As: Front Area (2.57m2) Cd: Air resistance coefficient (0.3)
V: Velocity (m/sec) r: Rolling resistance coefficient (0.006)

The driving power and the braking power are calculated by using digitized velocity change during one second by following equation.

$$dV/dt=(V(t+1) - V(t)) / dt$$

Driving Power E = D x V (Newton m/sec= Watt)
Braking Power EB= B x V (Newton m/sec= Watt)

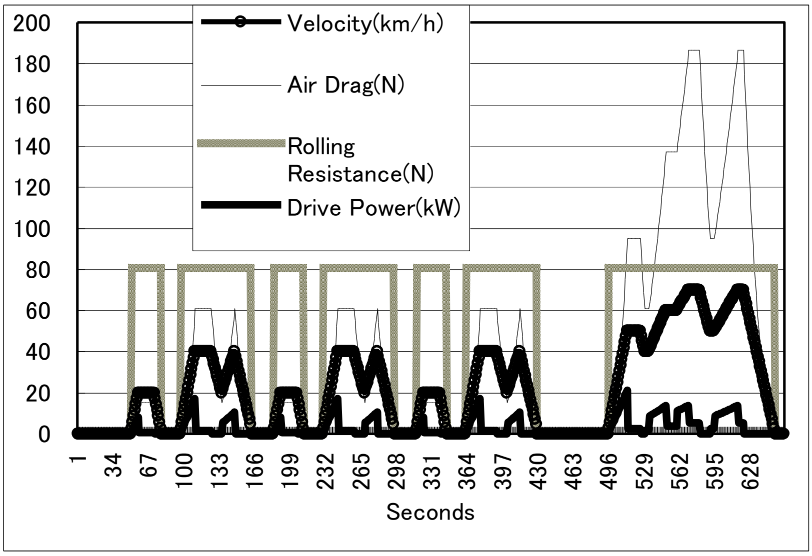

Fig.1 Drive Power calculation based on 10-15 mode driving test data

Simulation of Driving Performance

Fig.2 shows the concept of HFCVP. HFCV and HFCVP use regenerative brakes and recover electricity from rotation energy of wheel with 50% efficiency.

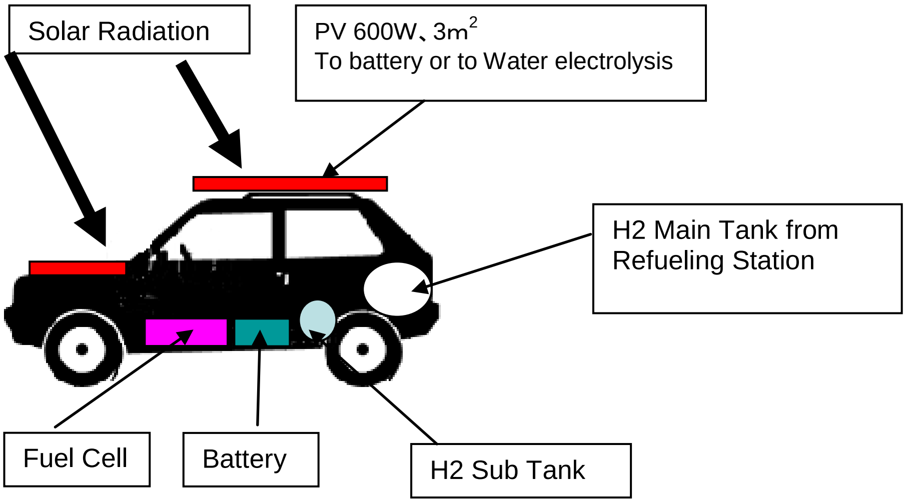

Fig.2 HFCVP
(Hybrid Fuel Cell Vehicle with regenerative brake and rooftop PV)

As the electricity cost on vehicles is estimated as high as 40 cents per kWh, it is economically feasible to apply PV at rooftop of vehicles, even at present PV cost. Technologies for innovative vehicle design such as battery, PV, water electrolysis and fuel cell are surveyed.

The realistic driving power for medium sized passenger car is estimated by analyzing the 10-15 mode driving test data. The dynamic simulations are performed for three types of fuel cell vehicle design, such as FCV, HFCV and HFCVP, using one minute solar radiation data in five cities in Japan throughout a year. Cost, hydrogen consumption and CO2 emission are compared.

The results show that HFCV saves 20% hydrogen, and HFCVP saves 40% hydrogen approximately against FCV. The total of vehicle cost and hydrogen cost in ten years for HFCV is less than FCV and that of HFCVP depends on the future PV cost. If the PV cost shall decrease along with learning curve, HFCVP will be a realistic option. Especially it will be effective in the countries with rich solar radiation.