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A statistical survey and analysis of HEV fuel consumption on Beijing Olympic Bus Line

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Abstract

According to the HEV application on 2008 Beijing Olympic Games, the comparative experiment and research of HEV fuel consumption and traditional bus fuel consumption are put forward. Proper experiment method of fuel consumption is chosen according to the Olympic Games passenger flow and fixed bus operation line. Experiment result of HEV economic advantage, effective way to improve the fuel economy and HEV integration technology are researched and summarized.

Keywords: HEV (hybrid electric vehicle), fuel consumption, passenger flow

Introduction

New energy vehicle becomes a key solution to the energy crisis and environmental problems, and has many potential social benefits. It is necessary and urgent to solve the transportation energy consumption problems.

It has been widely recognized that HEV is an important phase of the new energy vehicle improvement [1]. The 2008 Beijing Olympics had a theme of “Green Olympics, High-tech Olympics, and People’s Olympics”. Besides the zero emission Olympic center, there are Olympic bus lines all over the city of Beijing. In order to emphasize the “Green Olympics”, there are several green Olympic bus lines. One of the largest passenger flow volume bus line has been chosen for the statistical survey of the HEV fuel consumption.

2. Statistical survey of Hybrid-electrical vehicle bus

According to “Measuring the exhaust emissions and fuel economy of hybrid-electric vehicles” SAE J1711-1999 and “Test methods for energy consumption of light-duty hybrid electric vehicle”

GB/T19753-2005, for a certain working condition, fuel consumption experiment should be taken on a chassis dynamometer in a lab [2]. In order to put more environmental factors into the consideration, and get an accurate statistical survey data of the HEV application, the experiment is on a picked bus line, using the similar lab criterion.

2.1 Traditional vehicle fuel consumption measuring method

The traditional vehicle fuel consumption can be summarized as direct method and indirect method.

Direct method is widely applied:

1) Fuel flow measurement: using the flowmeter to get the fuel consumption;
2) Full fuel tank measurement: fill up the fuel tank to measure fuel consumption of each vehicle operation circle;
3) Real time measurement of fuel consumption meter.

Indirect method is more complex:

1) Cumulative method of fuel injection dose: measuring the ECU injection signal, and calculates the cumulative fuel consumption;
2) Air/fuel ratio method: measuring the air dose and air/fuel ratio, and calculated the cycle fuel consumption and total fuel consumption;
3) Carbon-balance method: the popular international laboratory fuel consumption measurement, taking the emission sample of CO_2, CO, HC and so on to calculate the total fuel consumption.

2.2 HEV fuel consumption measuring method

(1) Vehicle sample

There are two types of HEV buses in this experiment, both with diesel generators, recognized as TypeⅠ, TypeⅡ. Each type has 2 vehicles, which is 1#, 2# for TypeⅠ, and 3#, 4# for TypeⅡ. 2 traditional diesel generator buses are 5#, 6# for Type III. 35 circles of experiment is designed for the 6 buses. Bus parameters are as Tab 1-1.

Tab.1 Correlative parameters of chosen vehicle types for testing

Vehicle type	Curb mass /kg	Max mass /kg	Contour dimension /mm	Motor power /kW	Electrical motor power/kW	Power battery
TypeⅠ	12000	18000	11995×2546×3200	162	30	336V/40Ah NiMH
TypeⅡ	12300	17500	11880×2540×3300	118	60	336V/40Ah NiMH
TypeⅢ	12300	18000	11980×2545×3050	165	/	/

(2) Measuring methods

The experiment HEV samples have characteristics of great unladen mass, large passenger flow and complex working condition. The carbon-balance method which applied widely on light vehicle fuel consumption measurements is not suitable for this experiment [3]. The full fuel tank direct measurement is applied in this research because of the obvious error of fuel flow measurement and full fuel tank measurement.

In order to ensure the fuel consumption accuracy, the fuel charging method is summarized as follows:

① 6 HEVs should be filled up at the same oil station and with the same oil gun to ensure the fuel quantity and consistency.

② 6 HEVs should drive in the oil station in the same routine and same oil-filling location in order to remove the oil surface control error of road roughness.

③ There should be 5-10 minutes holding time after oil filling to reduce the oil foam effect.

(3) Similar working condition principle

The Bus line has complex working condition, great passenger flow change. In order to ensure the experiment consistency, multi-vehicle types are mixed to operate on the same bus line. The vehicle departure order: 3#→5#→1#→4#→6#→2#.

According to the environment temperature, state of air condition is medium ventilation with the target temperature of 26℃. And the air condition state can not change in a single operation circle. The assumption of HEV is all with the same original SOC.

(4) Data collection

Experiment time, odometer data of single operation circle, environment temperature, air-condition state, passenger flow of each bus stop, traffic condition and fuel quantity are collected during each experimental circle.

2.3 Statistical survey

Purpose of the statistical survey is to analyze the fuel economizing effect. So the rate of economizing fuel, fuel consumption of 100km, and fuel consumption of 100km per ton are calculated.

$$a = 100 \times L/(s_2 - s_1) \tag{1}$$

$$b = 100 \times \frac{L}{(m_v + m_p)(s_2 - s_1)} \tag{2}$$

$$Rate = (f_t - f_{hev})/f_t \times 100\% \tag{3}$$

a，fuel consumption per hundred kilometres（L/100km）;L，fuel quantity of one single operation circle; s_1， starting odometer data(km); s_2， end odometer data(km); b ,fuel consumption per hundred km per ton; m_v，vehicle integration mass（ton）; m_p，passenger mass of single operation circle（ton）.

Besides, the passenger flow volume is important to affect the vehicle mass and the fuel consumption. The single passenger flow is irregular as Fig.1. So the average statistical methods are taken to show the relationship between the passenger flow and fuel consumption.

$$V_{average} = \frac{\sum_{j=1}^{n} V_j}{n} = \frac{\sum_{j=1}^{n}\left[\sum_{i=1}^{j}(I_i - O_i)\right]}{n} \tag{4}$$

$V_{average}$,average passenger flow of each operation circle； V_j is the passenger number of the No.*j* bus stop； I_i ,getting on passenger number of No.*i* bus stop; O_i getting off number of No.*i* bus stop; n, number of bus stop of one single operation circle.

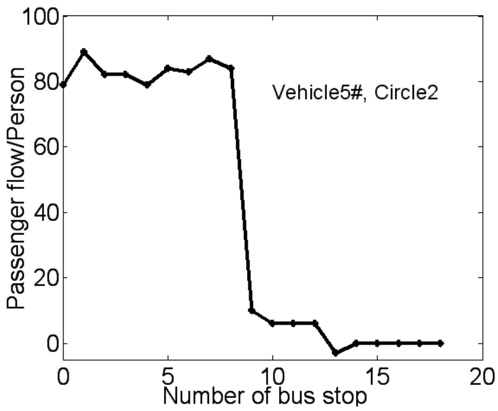

Fig.1 Passenger flow volume of traditional vehicle (5#) in Circle2

3. Analysis of the statistical survey

3.1 Passenger flow volume analysis

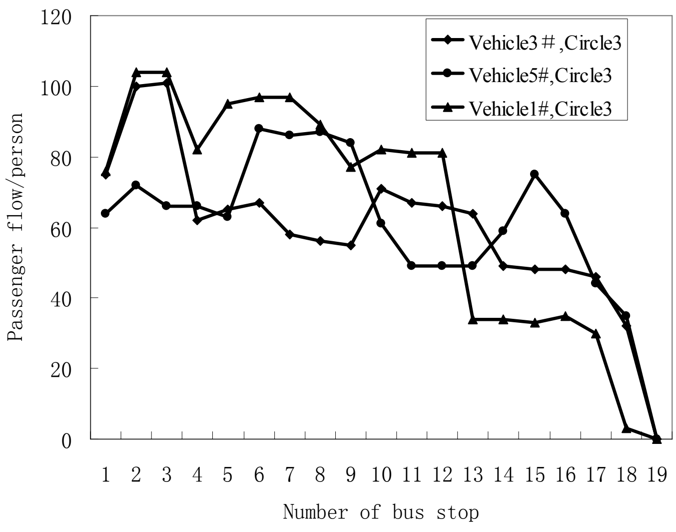

Fig.2 Passenger flow volume trend of vehicle3#, 5#,1# in circle3

Take circle 3 for example, the vehicle operates with the same departure order. Vehicle 1#,2#,3# of HEV type Ⅰ, type II and traditional vehicle are chosen to do the passenger flow volume analysis. Passenger flow volumes are similar as fig.2 shows. And the fuel consumption parameters such as fuel consumption per 100km, vehicle velocity and fuel consumption of 100km per ton are analyzed. As fig.3 shows, the vehicle velocities are similar to each other. And with the similar passenger flow and vehicle velocity, traditional vehicles have larger fuel consumption.

3.2 HEV & Traditional vehicle comparison

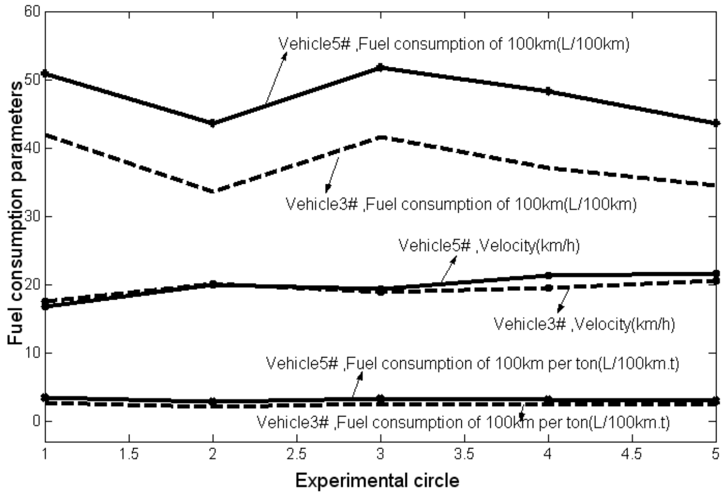

Fig.3 Fuel consumption comparison of traditional vehicle and HEV

(1) Fuel consumption comparison of traditional vehicle and HEV under similar passenger flow volume

Tab.2 Fuel consumption of different vehicle types in similar passenger flow condition

Type/Num.	Average passenger flow/person	Fuel consumption of 100km/(L/100km)	Fuel consumption of 100km per ton/（L/100km*T）
Type Ⅱ/3#	48.53	37.7008	2.4008
Type Ⅱ/2#	48.44	40.8728	2.5842
TypeⅢ/6#	47.43	49.1612	3.1450

(2) Fuel consumption of different electric accessories

During the experiment circles, temperature is always above 20℃, air-condition is one of the main energy consuming parts.

Tab.3 Fuel consumptions of 100km under different accessories

State of Air-condition	Vehicle 1# /L	Vehicle2# /L	Vehicle 3# /L	Vehicle 4# /L	Vehicle 5# /L	Vehicle 6# /L
On	42.0483	43.2468	40.1391	42.4821	50.2707	51.7167
Off	36.6693	37.95437	33.5906	34.3125	43.6434	46.8441

(3) Average fuel consumption

Tab.4 Average fuel consumption

Statistical data/Type	Type Ⅰ	Type Ⅱ	TypeⅢ
Average fuel consumption of 100km(L/100km)	39.83	38.50	48.21
Average fuel consumption of 100km per ton(L/100km·t)	2.56	2.44	3.13

4 Conclusions

Hybrid electric bus is suitable for city working condition of large passenger flow, frequent starts and stops. According to the fuel consumption experiment on certain bus line, a large passenger flow volume, warm climates, vehicle velocity and the electric accessory parts are considered.

(1) Rate of economizing fuel under a certain working condition is calculated. The large passenger flow, warm climate (above 20℃), low speed working condition draw the rate to 18.38%, which has great benefits to the environment.

(2) Under the certain dynamic power, control strategy optimizing is an effective way to improve the HEV fuel consumption. Different control strategy ends with different rate of economizing fuel (Type Ⅰ, 17.38%; Type Ⅱ, 19.38%).

(3) Proper motor power with a proper control strategy can improve the application. Type Ⅱ with a low power motor is more suitable for the experimental working condition.

(4) Accessory parts consume over 20% energy in the experiment working condition with the environment temperature above 20℃. So the selection and the application of proper electric accessory parts are important.

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