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Construction of Single Evaporative Emission Model and Analysis of Emission Characteristics for Gasoline Vehicles

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Abstract. To calculate the proportion of evaporative emissions of the China VI, this paper establishes a single-vehicle evaporative emission model for light gasoline vehicles, and an activity level model based on the car use habits of the employees of China Automotive Technology Research Center Co., Ltd. The proportion of evaporative emissions from Vehicle-A and Vehicle B, the running loss emissions of both Vehicle-A and Vehicle B account for over 50%, while refueling emissions and the diurnal 48-hour emissions account for lower proportions. The total annual evaporative emissions of vehicle A can reach 353.496 g, and the total annual evaporative emissions of vehicle B can reach 589.758 g.

Keywords. Gasoline vehicle, evaporative emission model, refueling emission, running loss emission

1. Introduction

There are many factors contributing to vehicle evaporative emissions [1], mainly including internal factors, environmental factors, oil factors, vehicle activity level, etc. [2]. The internal factors of the vehicle mainly include, for example, the adsorption capacity of the carbon canister [3], the proportion of different types of carbon powder, the design of the carbon canister and the fuel tank cap, and also the material of the valves at each connection of the oil circuit [4]. Environmental factors include ambient temperature and pressure changes [5].

The vapor pressure and composition of fuel have a great impact on the evaporative emissions and VOCs emission composition of vehicles [2]. The major constitutes of evaporative emission are small alkanes, alkenes and aromatic hydrocarbons. Aromatics and alkenes contributed the largest portion in OFPs of every emission process [6]. A modeling study estimated a 3 ppb increase in O3 formation in Tokyo, Japan, due to evaporative emissions [7]. The vapor pressure of gasoline is closely related to vehicle evaporative emissions. The increase of gasoline vapor pressure will increase the pressure in the vehicle fuel tank, and then the larger adsorption capacity of the carbon canister is needed. The increase of gasoline vapor pressure will increase the evaporative emissions of infiltration, and the gasoline vapor pressure in the underground oil storage tank [8], which will lead to the increase of emissions in all aspects of evaporative emissions and will not be conducive to the prevention and control of evaporative emissions. The

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temperature in the tropics and other regions is high in summer will lead to an increase in evaporative emissions, so the vapor pressure of gasoline in summer should be reduced. In winter and cold zones, the temperature is low, and the evaporative emissions are low, so the cold starting of the car is difficult.

Primarily, the frequency of vehicle use and parking time affect the diurnal emission level of the vehicle as both of these issues have a big influence on the desorption of the carbon canister. Because the diurnal emissions are mainly absorbed by the carbon canister, and the absorbed oil and gas are desorbed in the engine operating condition and then enter the engine combustion to prepare for the next step of vapor adsorption. If the vehicle parking time is too long, exceeding the adsorption capacity of the carbon canister, a large number of uncontrollable hydrocarbon emissions will be generated [9].

From I stage to V stage, China has adopted more European standard test methods. China VI puts forward strict requirements on the control of gasoline evaporative emissions. At the same time, it also requires vehicles to install the ORVR system, which increases the oil and gas control during refueling but has not yet involved the running loss.

Through the experimental research on two vehicles of evaporative emissions, refueling emissions, and running loss emissions, the emission factors under different evaporation forms are obtained, and a single-vehicle evaporative emissions model is established.

2. Test Scheme

2.1. Test Equipment

The test equipment shown in Figure 1 mainly includes PZEV VT-SHED [10, 11], fuel car, running loss SHED and dyno, canister treatment system, and other auxiliary equipment. The running loss test chamber is built by WEISS Company and consists of an airtight chamber, airbag, fresh air system, fuel tank heating system, temperature control system, etc. The dyno is built by Maha-AIP Corporation of Germany, and the maximum speed can reach 160 km/h. The dyno coating is made of low-emission materials to reduce the overall background emissions as much as possible. The canister treatment system is built by EST China, which can load and desorb canisters, and the loading rate and desorption rate meet the requirements of China VI [11].

(a) PZEV VT-SHED (b) Fuel cart (c) Running loss SHED and dyno (d) Canister BWC system

Figure 1. Equipment introduction.

2.2. Test Vehicle

Table 1 shows the information on the two test vehicles, which can meet China VI and are all new vehicles. Figure 2 shows the test photos of two sample vehicles.

Table 1. Test vehicle.

Type	Engine displacement	Emission stage	Mileage (km)	Fuel tank volume
Vehicle-A	1.6 L	China VI	8300	51 L
Vehicle-B	1.6 L	China VI	4219	46 L

(a) Vehicle-A (b) Vehicle-B

Figure 2. Test vehicle.

3. Construction of a Single-Vehicle Evaporative Emission Model

3.1. Calculation Model

This calculation model is only for total hydrocarbon. The test period is up to one year. Equation (1) can be modified according to the specific activity level of the vehicle, and finally, the HC emission level in a certain period can be calculated.

For the evaporative emission model of China VI vehicles, the evaporative standard limit is 0.7 g, and the refueling emission is 0.05 g/L. The evaporative emission model is shown in equation (1) below:

$$M_{HC} = T_1 \times \left(2 \times M_{1\text{h}} + M_{24\text{h}}\right) + T_2 \times \left(2 \times M_{1\text{h}} + M_{48\text{h}}\right) + T_3 \times \left(2 \times M_{1\text{h}} + M_{72\text{h}}\right) + L_1 \times M_{RL} + L_1 / 500 \times V_1 \times M_{\text{ORVR}} \quad (1)$$

where
T_1—Times of 24h;
T_2—Times of 48h;
T_3—Times of 72h;
L_1—Default 12000 km;
V_1—Fuel tank volume;
M_{1h}—HC emission during 1h hot soak;
M_{24h}—HC emission during diurnal 24h;
M_{48h}—HC emission during the second diurnal 24h;
M_{72h}—HC emission during the third diurnal;

M_{RL}—Running loss emission factor;
M_{ORVR}—Refueling emission factor.

3.2. Activity Level Construction

Table 2 is for data statistics of the in-service staff from China Automotive Technology Research Center. The employees' driving time and driving times per month are counted to obtain the heat soak pattern, diurnal soak pattern, refueling times, and actual running time pattern. One month is calculated as 30 days and four weekends. In Table 2, the average number of days at work is 18, the average number of weekend outings is 1.5, the total number of weekend outings is 6, and the total number of vehicle runs in a month is 48 (round trips). Each time the mileage is about 18 km, the vehicle running speed is 35 km/h, and each time is about 0.5 hours, so a total of 48 times in 24 hours, 48 hours for hot soak, 27 times during the daytime emissions, including 24.5 times in 24 hours, 2.5 times in 48 hours, 0 times in 72 hours, the number of refueling is calculated as 2 times. We calculate by 52 weeks a year.

Table 2. Activity level.

ID	Driving times	Outgoing times at weekend	Number of refuels per month	Kilometers per trip (km)	ID	Driving times	Outgoing times at weekend	Number of refuels per month	Kilometers per trip (km)
1	20	1-2	1-2	7	27	20	2	2	28
2	20	1	2	15.8	28	20	0-2	1-2	1.8
3	16	2	2	14	29	20	1-2	1-2	3
4	16	2	2	15	30	16	2	2	30
5	20	2	2	24	31	16	0-2	2	28
6	16	0-2	2	19.2	32	20	2	2	19
7	16	1-2	2	22	33	16	2	2	14
8	20	2	2	46	34	16	1-2	1-2	15
9	20	2	2	15	35	16	2	1-2	22
10	20	1-2	2	26.5	36	16	1-2	1-2	13
11	16	2	2	27	37	16	2	2	28
12	16	2	2	18	38	16	2	2	14
13	16	2	2	21	39	20	1-2	2	16
14	20	1-2	2	17	40	20	2	2	19
15	20	2	2	15.8	41	16	1-2	1-2	15
16	20	1-2	2	21	42	16	1-2	1-2	14
17	16	1-2	2	18	43	16	2	2	20
18	20	2	2	19	44	16	0-2	1-2	15
19	20	2	2	16	45	20	2	2	6
20	16	2	2	15	46	16	0-2	2	19
21	16	1-2	1-2	14	47	20	2	2	3
22	20	1-2	1-2	13	48	20	1-2	2	2
23	20	2	2	23	49	20	2	2	28
24	16	1-2	1-2	18	50	16	2	2	16
25	20	1-2	1-2	19	Average	18	min 0, max 2	min 0, max 2	17.942
26	20	1-2	2	29					

4. Analysis of Test Results

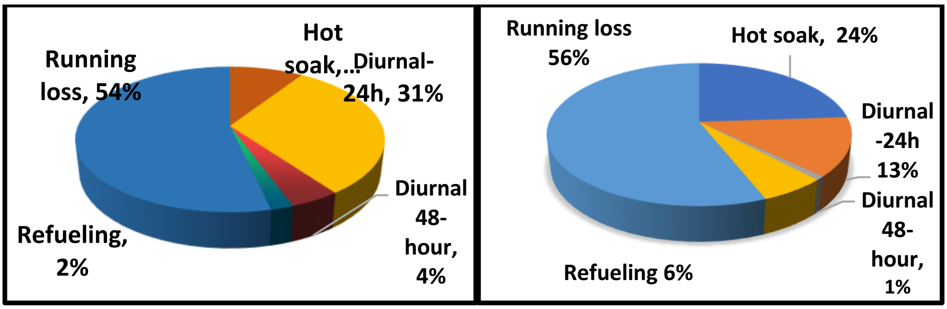
Table 3 shows the evaporative emission level of vehicles in different emission stages which is calculated based on equation (1) and Table 2 activity level.

Table 3. Vehicle evaporative emission levels.

ID	Hot soak (g)	Diurnal 24-hour (g)	Diurnal 48-hour (g)	Refueling (g)	Running loss (g)
Vehicle-A	2.496	8.379	1.210	0.544	14.563
Vehicle-B	10.848	6.027	0.375	2.714	25.406

Figure 3 shows the comparison of evaporative emission results of two vehicles. From the figure, it can be seen that the running loss emissions of both vehicles account for over 50%, while refueling emissions and the diurnal 48-hour emissions account for lower proportions. The main reason is that on the one hand, the vehicles in China 6 do not have effective control requirements for running loss emissions, but have implemented effective control measures for evaporation and refueling emissions; due to the relatively low frequency of refueling and the occurrence of diurnal 48-hour, overall, the proportion of refueling emissions and the diurnal 48-hour emissions is relatively lower. There is a significant difference in the hot soak results between Vehicle A and Vehicle B, mainly due to two reasons. On the one hand, there are differences in non-fuel evaporative emissions between different vehicles (tires, interior and exterior decorations, etc.), and for vehicle A, non-fuel evaporative emissions may themselves be higher than Vehicle B; On the other hand, control logic for different evaporative emission stages varies depending on the carbon canister configuration of different vehicles. The carbon canister of vehicle A may have a stronger adsorption capacity for the generated fuel vapor during the hot soak stage, while vehicle B is weaker. In the diurnal evaporation process, it is mainly to test whether the carbon canister adsorption capacity and the fuel system's permeability and emission control capacity meet the regulatory requirements.

Based on equation (1), the total annual evaporative emissions of vehicle A can reach 353.496 g, and the total annual evaporative emissions of vehicle B can reach 589.758 g.



(a) Vehicle-A (b) Vehicle-B

Figure 3. The proportion of evaporative emissions.

5. Conclusion

Based on two light-duty gasoline vehicles test, and research on the vehicle habits of Chinese residents, the research conclusions are as follows:

(1) A single-vehicle evaporative emission model is established, and an activity level model is established based on the vehicle habits of Chinese residents.

(2) Based on the models, the proportion of evaporative emissions from two vehicles is analysed as, the running loss emissions of both vehicles account for over 50%, while refueling emissions and the diurnal 48-hour emissions account for lower proportions.

(3) According to the single-vehicle evaporative emission model based on equation (1), the total annual evaporative emissions of vehicle A can reach 353.496 g, and the total annual evaporative emissions of vehicle B can reach 589.758 g.

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