E3S Web of Conferences **360**, 01022 (2022) https://doi.org/10.1051/e3sconf/202236001022
VESEP2022

Experimental study on working capacity of carbon canister based on Euro VI

Jiaxing Sun[1], *Zhengjun* Yang[1], *Di* Peng[2,3,*], *Chongzhi* Zhong[1], *Taiyu* Zhang[1], and *Zhe* Li[1]

[1] China Automotive Technology and Research Center Co.,Ltd, Tianjin 300300, China
[2] State Environmental Protection Key Laboratory of Vehicle Emission Control and Simulation, Chinese Research Academy of Environmental Sciences, Beijing 100012, China
[3] Vehicle Emission Control Center, Chinese Research Academy of Environmental Sciences, Beijing 100012, China

Keywords: Carbon canister, Gasoline working capacity, Butane working capacity, Durability.

Abstract. In order to study the gasoline working capacity and durability of the carbon canister, the gasoline working capacity test of the carbon canister was conducted under different test conditions. The results showed that the gasoline working capacity of the canister carbon decreased with the increase of fuel vapor loading rate. The fuel vapor volume ratio of the inlet has little effect on the gasoline working capacity. After 300 gasoline working capacity test cycles, the working capacity of butane decreased by about 20% . The fuel vapor adsorption amount in first cycle of each carbon canister is far greater than the desorption amount in first cycle, and also far greater than the adsorption and desorption amount in the subsequent cycles, which indicated that a large amount of fuel vapor occupied the active sites after the first use of the carbon canister and cannot desorb.

1 Introduction

Hydrocarbon (HC) is one of the main pollutants of light-duty vehicles, and fuel evaporative emission accounts for about 20% of the total HC emission[1]. The evaporative emission from light-duty vehicles regulated in China 6 emission standard shall not exceed 0.7g/test, and the deterioration factor value of 0.06g/test is also added, which means the sum of the experiment result and the deterioration factor can not be greater than 0.7. Compared with the China 5 evaporative emission standard, the limit value is 65% stricter. In addition, the China 6 evaporative emission standard also learned from the US emission standards, and the refueling emission test was added in, and the emission limit of 0.05g/L was regulated with a deterioration factor 0.01g/L. The more stringent requirement was put forward for vehicle evaporative emission control technology. As the core component of evaporative emission control system, working capacity and durability characteristics of the carbon canister are the key indicators to measure whether the evaporative emission of

* Corresponding author: pengdi@vecc.org.cn

vehicles in use conforms to the standard. There were a lot of researches showed that we should pay more attention on the control of the vehicle evaporative emission. In Japan, the sixth-highest source of VOCs was gasoline evaporative evaporation from vehicles[2]. A small-sized vehicle could produce approximately 1000g evaporative emissions in one year at two Italian provinces which was researched by Martini et al.[3] . Liu et al.[4] and Man et al.[5] did a lot of research work, and found that evaporative emissions are increasingly crucial to total VOCs emissions in China.

This paper focuses on the changes of gasoline working capacity (GWC) and butane working capacity (BWC) of light duty gasoline vehicle carbon canister under different test conditions, so as to achieve the purpose to research the carbon canister working capacity and durability characteristics and understand the decay of the carbon canister working capacity in the actual use process.

2 Working principle and test method of carbon canister

2.1 Working principle of carbon canister

When the vehicle is in the process of driving or parking, the fuel vapor generates from the fuel tank and enters in the carbon canister for storage through the pipe and the adsorption port. When the vehicle is in the process of refueling, the fuel vapor produces at a faster speed, which leads to the rise of the pressure in the tank. Due to the influence of pressure difference, the fuel vapour enters in the carbon canister for storage. When the engine is on and reaches a certain speed, the negative pressure caused by the engine intake system makes the ambient air enters in carbon canister from the air port. And the ambient air will purge the carbon canister, and the absorbed fuel vapor will desorb from the carbon canister and be brought into the engine for combustion, so as to control the fuel evaporation emission of the whole vehicle.

The carbon canister is mainly composed of shell, filter cloth, activated carbon, ports and other components. The inner part of the carbon canister is divided into several chambers, including mixing chamber, fuel volatile chamber and buffer chamber[6].The selection of activated carbon plays a decisive role in the working capacity of carbon canister. Activated carbon has developed pore structure and large specific surface area which can help to adsorb a large amount of fuel vapor effectively. Due to the effect of van der Waals force, fuel vapor can be adsorbed on the surface of carbon particles. Under the condition of airflow disturbance, the fuel vapor can break away from the van der Waals force and move with the airflow. The working capacity of activated carbon mainly depends on pore structure, porosity and pore surface area. According to the pore size, pores can be divided into micropore, mesopores and macropores. Micropores can effectively adsorb fuel vapor, but it is difficult to desorb. Mesoporous pores can effectively adsorb and desorb fuel vapor; Although macropores can not effectively absorb fuel vapor, they can provide channels for fuel vapor molecules to enter and exit. After repeated use of adsorption and desorption, fuel vapor molecules in the pores can not completely desorb and occupy part of the pore structure, which leads to the decline of the working capacity of the carbon canister. The main reason for the aging of the gasolin working capacity of the carbon canister is that fuel vapor molecules in the pores can not completely desorb.

2.2 Test method of carbon canister working capacity

2.2.1 Test method of gasoline working capacity

Each test cycle is mainly divided into two parts: adsorption stage and desorption stage. The working principle of the test equipment for the gasoline working capacity of carbon canister is shown in Figure 1. In the adsorption stage, the fuel vapor and nitrogen are mixed with the volume ratio of 1:1. The fuel vapor is loaded on the carbon canister at a loading rate of 60g/h until the weight of the auxiliary carbon canister increases by 2g which also called 2g breakdown. In the desorption stage which started within 10 minutes after the carbon canister reaches 2g breakdown, the air in the laboratory is used to purge the carbon canister with a rate of 25±5 L/ min until the total purge volume reaches 300 times bed volume of the carbon canister. The combination of each adsorption stage and desorption stage is a complete GWC test cycle.

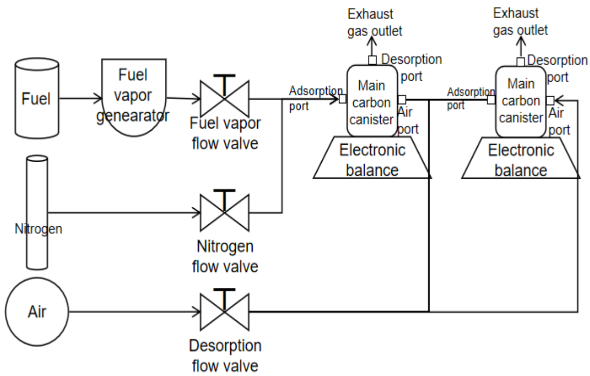

Fig. 1. Schematic diagram of gasoline working capacity test equipment.

2.2.2 Test method of butane working capacity

Each test cycle is mainly divided into two parts: adsorption stage and desorption stage. The working principle of the test equipment for the butane working capacity of carbon canister is shown in Figure 2. In the adsorption stage, the butane and nitrogen are mixed with the volume ratio of 1:1. The butane is loaded on the carbon canister at a loading rate of 40g/h until the weight of the auxiliary carbon canister increases by 2g which also called 2g breakdown. In the desorption stage which started within 10 minutes after the carbon canister reaches 2g breakdown, the air in the laboratory is used to purge the carbon canister with a rate of 25±5 L/ min until the total purge volume reaches 300 times bed volume of the carbon canister. The combination of each adsorption stage and desorption stage is a complete BWC test cycle.

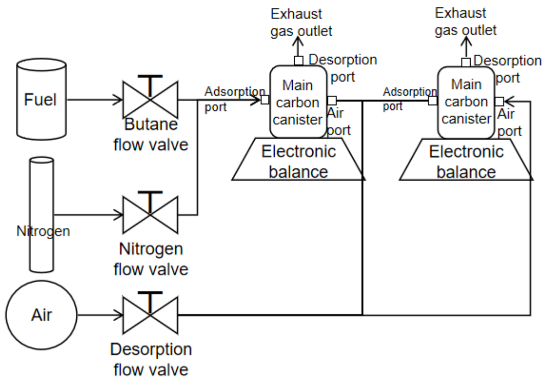

Fig. 2. Schematic diagram of butane working capacity test equipment.

2.3 Test conditions for the research of gasoline working capacity of carbon canister

The butane gas and E10 fuel conforming to Euro 6 d standard is used. The Reid vapor pressure of the E10 fuel is 57.1kpa. And the purity of the butane gas is 99.9%. The laboratory environmental temperature is maintained at 23 ± 5℃;

(1) The effect of the fuel vapor loading rate on gasoline working capacity was researched as following. The same carbon canister was used, the volume ratio of the fuel vapor and nitrogen is set to 1:1, and the loading rate of fuel vapor is set to 45g/h and 60g/h respectively. The test process was according to the test method of 2.2.1.

(2) The effect of the volume ratio of fuel vapor and nitrogen on the gasoline working capacity was researched as following.The same type of carbon canister was used, the fuel vapor loading rate was set to 60g/h, the volume ratio of the fuel vapor and nitrogen is set to 1:1 and 6:4 respectively. The test process was according to the test method of 2.2.1.

(3) The effect of GWC cycle number on the gasoline working capacity was researched as following. Four different types carbon canisters were used in this research. The loading rate of the fuel vapor is set to 60g/h, the volume ratio of fuel vapor and nitrogen is set to 1:1, and each carbon canister was aging treated with 300 GWC cycles respectively. The test process was according to the test method of 2.2.1.

(4) The change of butane working capacity before and after the 300 GWC test cycle aging treatment was researched. The test condition and method were according to the test method of 2.2.2.

3 Study and analysis on the working capacity and durability of carbon canister

3.1 Effect of the fuel vapor loading rate on gasoline working capacity

The volume ratio of fuel vapor and nitrogen is set to 1:1. According to the test method of gasoline working capacity of 2.2.1 and the test conditions according to 2.3 (1) , three GWC test cycles of the same carbon canister were carried out at the fuel vapor loading rate of 60g/h and 45g/h respectively. The difference of gasoline working capacity of carbon canister under two test conditions is compared. The experimental results are shown in Table 1 and Figure 3.

Table 1. Gasoline working capacity of the carbon canister at the fuel vapor loading rate of 60g/h and 45g/h

Cycle number	GWC of fuel vapor loading rate 60g/h (g/100mL)	GWC of fuel vapor loading rate 45g/h (g/100mL)
1	4.3211	4.0356
2	4.3456	5.3689
3	4.3744	5.2189
Mean value	4.3470	4.8745

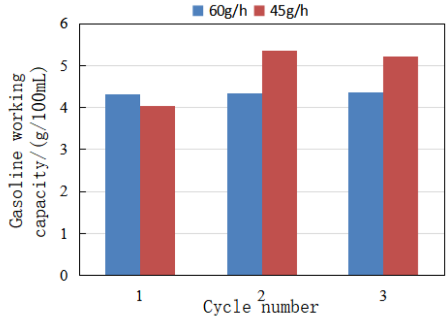

Fig. 3. Gasoline working capacity of the carbon canister at the fuel vapor loading rate of 60g/h and 45g/h.

With the fuel vapor loading rate was reduced to 45g/h, the gasoline working capacity of the carbon canister increased by 0.5275g/100ml corresponding to 12.13% growth ratio. The main reason is that the fuel vapor molecules contact with activated carbon more fully with the decrease of the loading rate of the fuel vapor, and the activated carbon can better absorb fuel vapor molecules. In addition, the high loading flow rate will easily make the fuel vapor molecules adsorbed on the surface of activated carbon free from van der Waals force, which contributed to the reduction of the gasoline working capacity of the carbon canister.

3.2 Effect of the volume ratio of fuel vapor and nitrogen on the gasoline working capacity

The loading rate of fuel vapor is set to 60g/h. According to the test method of gasoline working capacity of 2.2.1 and the test conditions of 2.3 (2), GWC test cycles on the same carbon canister were carried out at the fuel vapor and nitrogen volume ratio of 1:1 and 6:4 respectively. Three GWC test cycles were carried out under each volume ratio. The difference of gasoline working capacity of the same carbon canister under two test conditions is compared. The experimental results are shown in Table 2 and Figure 4.

Table 2. Gasoline working capacity of the carbon canister at the fuel vapor volume ratio of 1:1 and 6:4.

Cycle number	GWC of volume ratio 1:1(g/100mL)	GWC of volume ratio 6:4(g/100mL)
1	4.3211	4.4083
2	4.3456	4.4072
3	4.3744	4.4167
Mean value	4.3470	4.4107

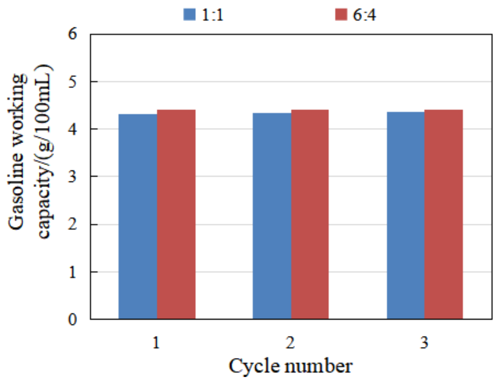

Fig.4. Gasoline working capacity of the carbon canister at the fuel vapor and nitrogen volume ratio of 1:1 and 6:4.

By increasing the proportion of fuel vapor of the inlet from 50% to 60%, the gasoline working capacity of carbon canister was increased by 0.0637g/100ml, and the working capacity growth percentage was increased by 1.47%. When the loading rate of fuel vapor remains unchanged, a small increase in the proportion of fuel vapor of the inlet has no significant effect on the gasoline working capacity of the carbon canister. More studies under different fuel vapor and nitrogen volume ratio was need to study this point.

3.3 Effect of GWC cycle number on the working capacity of carbon canister

The ratio of fuel vapor and nitrogen is set as 1:1, and the loading rate of fuel vapor is set as 60g/h. According to the test method of gasoline working capacity of 2.2.1 and the test conditions of 2.3 (3), there were 4 carbon canisters, and 300 GWC test cycles were conducted for each carbon canister; The adsorption and desorption amount of fuel vapor from the four canisters in the first, second and 300th cycles are shown in Table 3 and Figure 5. The adsorption amount of each canister in the first cycle is much larger than the desorption amount in the first cycle, and the adsorption amount in the second cycle is also more than the desorption amount in the second cycle. However, the adsorption and desorption amount in the 300th cycle is basically the same. In addition, the adsorption amount of the canister decreased significantly from the first cycle to the 300th cycle.

Table 3. Fuel vapor adsorption and desorption at the first, second and 300th test cycle.

Canister number	Adsorption amount of cycle 1 (g)	Desorption amount of cycle 1 (g)	Adsorption amount of cycle 2 (g)	Desorption amount of cycle 2 (g)	Adsorption amount of cycle 300 (g)	Desorption amount of cycle 300 (g)
a	162.43	74.49	95.57	78.2	74.84	78.12
b	171.93	79.27	93.18	74.62	76.51	77.36
c	154.93	68.6	85.55	69.47	63.95	65.62
d	192.11	107.32	141.74	117.53	126.42	124.36

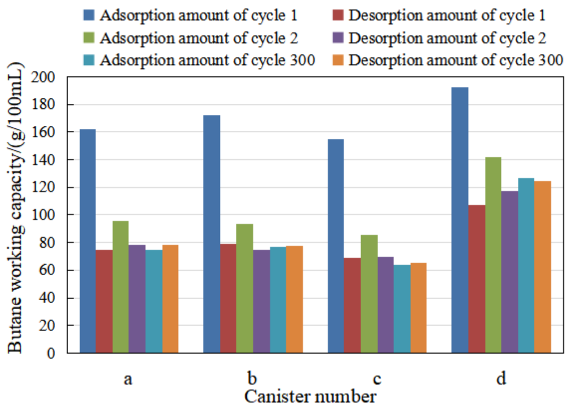

Fig. 5. Fuel vapor adsorption and desorption at the first, second and 300th test cycle.

After the completion of the 300 GWC test cycles, 10 BWC cycles were carried out for four carbon canisters according to the butane working capacity test method and test conditions in 2.2.2, and the average BWC of the last five cycles was taken as the butane working capacity of the carbon canister after aging treatment, which was compared with the initial declared butane working capacity value provided by the carbon canister manufacturer. which was to study the change trend of the working capacity of the carbon tank after aging treatment. The butane working capacity of each carbon canister at initial and after aging treatment

Table 4. Comparison of butane working capacity of each carbon canister at initial stage and after aging treatment.

Canister no.	BWC at Initial (g /100mL)	BWC after aging treatment (g /100mL)	Aging degree/ %
1	6.5	5.68	12.615
2	6.1	4.83	20.82
3	6.2	4.94	20.323
4	6.5	5.07	22

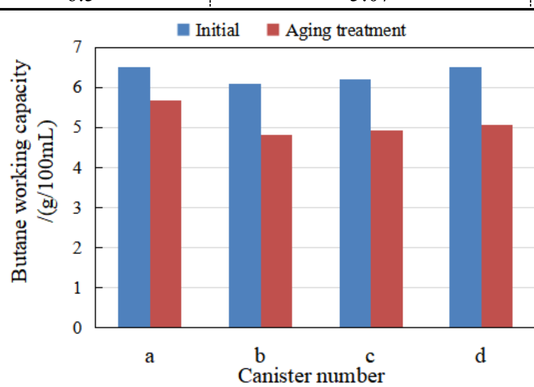

Fig. 6. Comparison of butane working capacity of each carbon canister at initial and after aging treatment.

After 300 GWC cycles of aging treatment, the butane working capacity of the carbon canister generally decreased by about 20%. The above results show that the fuel vapor plays an role of blocking micro pores after aging treatment. A large amount of fuel vapor will occupy the active sites after the first use of the carbon canister, which can not effectively desorb. After repeated use, the active sites blocked gradually increased. In the process of desorption, the amount of fuel vapor that can be taken away by a fixed total amount of purge air is limited. Finally, the amount of adsorption and desorption in each cycle reaches a relatively balanced state. The fuel vapor that cannot be completely desorbed occupies part of the active sites, and the amount of fuel vapor blocked the active sites determines the aging degree of the activated carbon.

4 Conclusion

(1) With the decrease of the fuel vapor loading rate, the gasoline working capacity of the carbon canister increased. The main reason is that the fuel vapor molecules contact more fully with the activated carbon when the loading rate of the fuel vapor is low, and the activated carbon can better absorb fuel vapor molecules. In addition, the high loading flow rate will easily make the fuel vapor molecules adsorbed on the surface of activated carbon free from van der Waals force, which contributed to the reduction of the gasoline working capacity of the carbon canister.

(2) With the increase of the fuel vapor volume ratio of the inlet by 10%, the gasoline working capacity of carbon canister increased by 0.0637g/100ml, and the working capacity growth percentage was 1.47%. When the loading rate of fuel vapor remains unchanged, a small increase in the proportion of fuel vapor of the inlet has no significant effect on the gasoline working capacity of the carbon canister.

(3) In the first and second GWC test cycle, the adsorption amount of each carbon canister is much larger than the desorption amount. However, the adsorption and desorption amount in the 300th cycle is basically the same. With the increase of the test cycle number, the adsorption amount of the carbon canister decreased significantly. A large amount of fuel vapor which can not desorb with the purge air will occupy the active sites after the first use of the carbon canister. With the increase of the test cycle number, the active sites occupied by fuel vapor which can not desorb with the purge air increased. Finally, the amount of adsorption and desorption in each cycle reaches a relatively balanced state. On the one hand, a part of fuel vapor that can be taken away by a fixed total amount of purge air. On the other hand, the active site blocked by fuel vapor is deteriorated.

(4) After the aging treatment of 300 gasoline working capacity test cycles, the butane working capacity of four carbon canisters were researched. The butane working capacity of four carbon canister decreased by about 20%. The amount of fuel vapor blocked the active sites determines the aging degree of the activated carbon.

References

1. Meng H: Evaporative emission control for gasoline car[J]. Quality and Standardization, 2018 317(09), 64-66.
2. Yamada H. Contribution of evaporative emissions from gasoline vehicles toward total VOC emissions in Japan[J]. Science of the Total Environment, 2013, 449(apr.1):143-149..
3. Martini G , Paffumi E , MD Gennaro, et al. European type-approval test procedure for evaporative emissions from passenger cars against real-world mobility data from two Italian provinces[J]. Science of the Total Environment, 2014, 487(1):506-520.
4. Liu H , Man H , Tschantz M , et al. VOC from Vehicular Evaporation Emissions: Status and Control Strategy[J]. Environmental Science & Technology, 2015, 49(24):14424-14431.

5. Man H , Liu H , Xiao Q , et al. How ethanol and gasoline formula changes evaporative emissions of the vehicles[J]. Applied Energy, 2018, 222:584-594.
6. Yang C, Zhang D: Analysis of design points of automobile carbon canister[J]. Internal Combustion Engine & Parts, 2017, 000(017):41-42.