Impact of Electric Heating Catalyst on the Emissions for a 48V Hybrid Light-duty Vehicle

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Abstract: The emission characteristics under worldwide harmonized light vehicles test cycle (WLTC) was investigated for a 48V hybrid light-duty vehicle which carried a 2.0 L naturally aspirated engine on engine test bed after the WLTC cycle was converted to the corresponding engine transient cycle. The influence of electric heating catalyst on exhaust emission was analyzed. The results show that electric heating catalyst can effecively speed up the temperature rise rate then significantly decreases the exhaust emission. Electric heating has a more pronounced effect for ceramic carrier catalyst.

Key words: Hybrid Light-duty Vehicle, 48V, Electric Heating Catalyst, Emissions

1. Introduction

With the increasingly stringent emission standards, the emission control technology of light-duty vehicles is also continuously enhanced. China has released China's sixth-stage emission standards for light vehicles (GB 18352.6-2016) in 2016 [1]. Apart from tightening pollutant emission limitation, a real driving emission (RDE) test was also added in this standard to effectively evaluate the emission of vehicle under actual road driving. The RDE test requires that the emission limit should be met under environmental conditions from -7°C to 38°C, which puts forward higher requirements for emission control under cold start conditions.

Cold start of a gasoline engine can cause both emissions and fuel consumption to deteriorate because richer mixture and poor fuel atomization will cause quenching effect of the cylinder walls so as to increase the pollutant formation. In addition, since the light-off temperature of the catalyst under cold start has not yet been reached, the catalytic efficiency at this time is extremely low. Elevated raw emissions and low catalytic efficiency together result in high emissions at cold start [2-3]. Moreover, compared with traditional light-duty vehicle, the engine of hybrid light-duty vehicle is frequently in the shutdown state, resulting in a drop in catalyst temperature and a dramatic increase in the exhaust pollutant emission [4].

In order to reduce emissions during cold starts and frequent start-stop phases, the time to reach light-off temperature of three-way catalyst (TWC) can be shortened by many efforts such as changing the catalyst arrangement, improving combustion or adding additional components [5-6]. However, the above methods have their own advantages and disadvantages. For example, the closer the TWC is to the engine outlet, the easier it is for TWC to reach the light-off temperature. However, in most working conditions, the catalytic converter will be in a high temperature state, which will seriously affect the life of TWC. In present, the emission at low temperature is mainly reduced by increasing the precious metallic content of the TWC and finer calibration, which will increase the cost. It is a feasible method to use an electric heating catalyst (EHC), which uses an external power source to heat the TWC to quickly reach the working temperature, shorten the catalyst light-off time, and improve the catalytic efficiency during the cold start stage [7-9]. Liu Min et al. used EHC to study the effects of heating voltage, heating time and the amount of precious metallic coating on the cold-start emission of gasoline engines [10]. However, there are few researches on the EHC for hybrid light-duty vehicle.

In this context, a 48V hybrid light-duty vehicle that meets the China VI emission standard was selected to run the worldwide harmonized light vehicles test cycle (WLTC) on engine test bed after the WLTC was converted into an engine bench cycle. The effect of changing the electric heating control strategy on different aftertreatment carrier materials on the engine bench was studied.

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2. Experimental Setup

2.1 Experimental test equipment

The experimental schematic diagram is shown in Figure 1.

Figure 1 Schematic diagram of the test system

The electric dynamometer, fuel consumption meter and gasous emission analyzer produced by Japan HORIBA company are used to accurately measure the engine speed, torque and gasous emission. The particle sampling system SPC and partile counter of Austria AVL company is selected to measure the quality and quantity of particulate pollutants.The main test equipment is shown in Table 1.

Table 1 Test equipment

Equipment name	Equipment Type and Manufacturer
Test bed control system	HORIBA STARS
AC Dynamometer	HORIBA HT350
Fuel consumption meter	HORIBA FQ-3100DP
Air flow meter	ABB Sensyflow FMT700-P
Gasous emission analyzer	HORIBA MEXA-ONE-D1-OV-EGR
Particle sampling system	AVL SPC 478
Particle counter	AVL 489
Weighing balance	Sartorius CPA2P-F
Weighing chamber	RX Tech RXCH-500

2.2 Tested engine

The test engine is a 2.0 Lnaturally aspirated engine that meets China VI emissions and is carried on a 48V hybrid light-duty vehicle with a rated power of 105 kW and a maximum torque of 180 Nm. The main parameters of this engine are shown in Table 1.

Table 2 Main parameters of tested engine

Parameter	Value
Intake form	Naturally aspirated
Bore×Stroke	79 mm×102 mm
Displacement	2.0
Rated power	105 kW
Maximum torque	180 Nm
Emission Control Technology Route	EGR+TWC+GPF
Emission Standards	China VI

2.3 Test cycle

The WLTC cycle was converted to a corresponding engine transient cycle, as shown in Figure 2 [11]. Due to the intervention of the motor, the corresponding engine speed is zero at low vehicle speed.

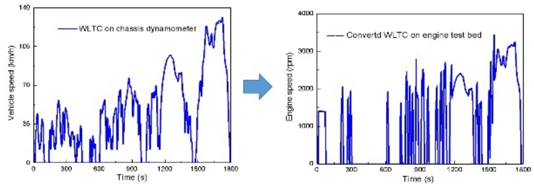

Figure 2 Converted WLTC on engine test bed

2.4 Test plan

Two type of catalyst carrier were tested on engine tese bed. One carrier is metallic material and another is ceramic material. Different electric heating strategies were applied as a comparison. The test plan is shown in Table 3.

Table 3 Test plan

Test No.	Catalyst carrier	Electric heating strategy
No.1	ceramic material	no heating
No.2	ceramic material	heating 40 seconds when cycle starts
No.3	ceramic material	heating 40 seconds after preheating 60 seconds
No.4	metallic material	no heating
No.5	metallic material	heating 40 seconds when cycle starts

3. Results and Discussions

3.1 Catalyst temperature using different carriers

Figure 3 shows the effect of diffrent carriers on catalyst temperature. Compared with the ceramic carrier, the ignition temperature is lower and the heating speed is faster for metallic carrier. From the enlarged image in the lower right corner of Figure 3, the time reach to catalyst temperature of 250 ℃ is 32 seconds for metallic carrier which is 5 seconds faster than ceramic carrier. The time reach to catalyst temperature of 600 ℃ is 47 seconds for

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metallic carrier which is 22 seconds faster than ceramic carriers. This is due to the lower specific heat capacity of metallic carrier, which increases the heating speed. However, the temperature drop speed of metallic carrier is also faster than ceramic carrier, as shown in places A and B.

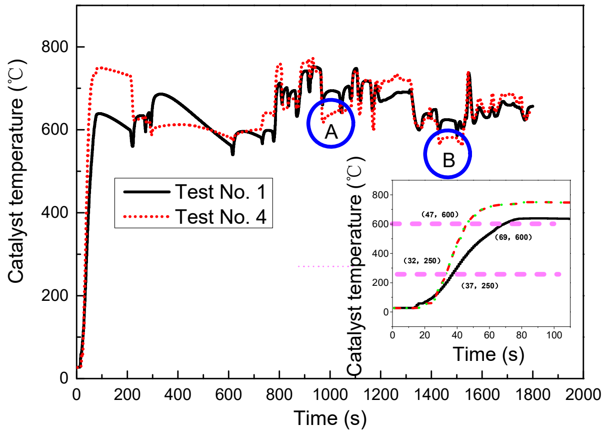

Figure 3 Catalyst temperature for different carriers

3.2 Electric heating ceramic carrier catalyst

Figure 4 shows the effect of electric heating ceramic carrier catalyst on catalyst temperature. Compared with the no heating test (Test No. 1), electric heating can rapidly increase the catalyst temperature. For Test No. 2, the catalyst temperature increase to 761 ℃ within 82 seconds. While the catalyst temperature increase to 811 ℃ within 85 seconds. Generally speaking, when the temperature of the catalyst reaches 600 ℃, the catalytic efficiency can reduce the emission of pollutants very well. The enlarged image in the lower right corner of Figure 3 shows the changes in the catalytic temperature in the first 100 seconds. The time to reach 600 ℃ is 69 seconds, 54 seconds and 46 seconds for Test No.1~3 respectivley. This indicated that the electric heating can help the catalyst reach light-off temperature faster, and a preheating has better consequent.

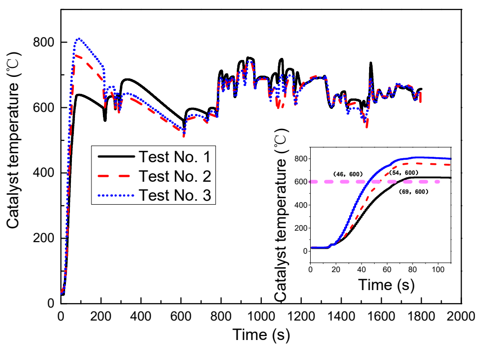

Figure 4 Ceramic carrier catalyst temperature for different heating strategies

Figure 5 shows the effect of electric heating ceramic carrier catalyst on exhaust emissions. Compared with the no heating test, the electric heating is conducive to the reduction of pollutant emissions. Total hydrocarbon (THC), carbon monoxide (CO), nitrogen oxides (NOx) and particle number (PN) decreases by 11%, 6%, 5% and 3% respectively when electric heating 40 seconds and by 44%, 11%, 32% and 72% respectively when electric heating 40 seconds after a preheating of 60 seconds. Preheating has a significant effect due to the effect of thermal radiation which increase the temperature of the surrounding pipeline and gas resulting in reaching light-off temperature more easily.

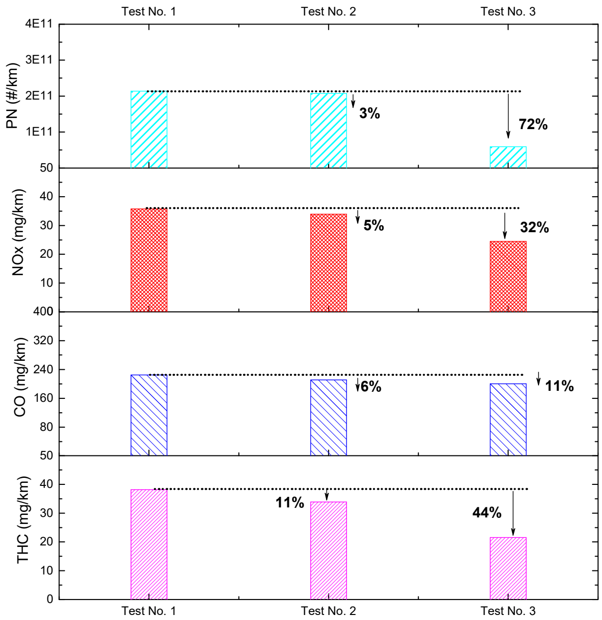

Figure 5 Exhaust emission for different heating strategies for ceramic carrier catalyst

3.3 Electric heating metallic carrier catalyst

Figure 6 shows the effect of electric heating metallic carrier catalyst on catalyst temperature. Compared with the no heating test (Test No. 4), electric heating can also increase the catalyst temperature. The time to reach 600 ℃ is 47 seconds and 39 seconds for Test No.4~5 respectivley. This indicated that the electric heating can help the catalyst reach light-off temperature faster. However, the heating effect is not as significant as ceramic materials probably due to the fast heating property of metallic carrier itself.

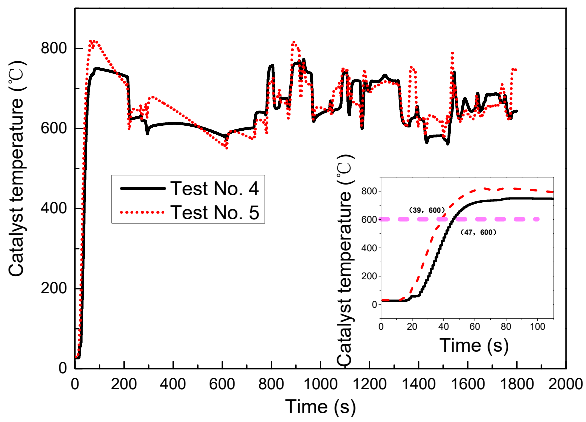

Figure 6 Metallic carrier catalyst temperature for different heating strategies

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Figure 7 shows the effect of electric heating metallic carrier catalyst on exhaust emissions. Compared with the no heating test, the electric heating is conducive to the reduction of THC, CO and PN, but significantly increases the NOx emission. THC, CO and PN decreases by 52%, 32% and 12% respectively when electric heating 40 seconds, but the NOx increases by 91%.

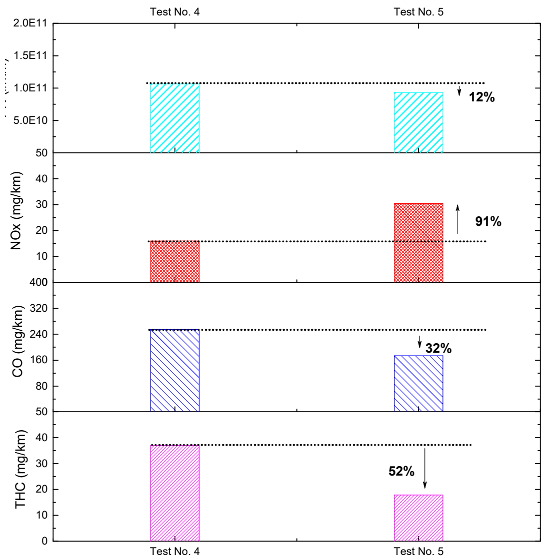

Figure 7 Exhaust emission for different heating strategies for metallic carrier catalyst

4. Conclusion

1) Compared with the ceramic carrier, the ignition temperature is lower and the heating speed is faster for metallic carrier.
2) Electric heating catalyst can effecively speed up the temperature rise rate then significantly decreases the exhaust emission. Electric heating has a more pronounced effect for ceramic carrier catalyst.

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