

Effect of different lubricating oil formulas on the adaptability of cGPF aftertreatment

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Abstract. Based on two different components of lubricating oil, this paper analyzes the filtration efficiency, ash accumulation speed, vehicle WLTC emissions, fuel consumption, and CT scan on a National V emission standard engine equipped with a cGPF aftertreatment device. The results show that both oils can ensure that cGPF meets the emission and fuel consumption requirements of National VI emission standard, but oil F accumulates ash quickly before the ash accumulation of 33% in the discharge, which has a significant effect on PN reduction, and oil C accumulates ash faster after the accumulation of 33%. The effect of reducing the PN is accelerated. Oil F is based on a full calcium detergent system, which has a trend of first to slower for the collection efficiency; while oil C is based on a mixed Ca/Mg detergent system, which has a trend of first slowing and then fasting the collection efficiency. The critical point is generally about 33% of accumulated ash. For oil F, less ash is deposited in the front and middle of the cGPF, while more ash tends to deposit towards the outlet. In contrast, cGPF aged with Oil C has a relatively uniform deposition distribution.

1 Introduction

With the continuous growth of population and energy consumption, emission control has become an important measure of ecological environment management^[1]. As the latest emission regulations tighten and the limits on automotive pollutants continue to decrease, GPF has become an effective technology for controlling exhaust pollutants^[2].

In addition, the quality of lubricating oil in the engine has an important influence on the exhaust performance, economy and durability of the vehicle^[3]. At present, studies have shown that the composition of lubricating oil additives will have a certain impact on the performance of cGPF.

By studying the effect of different lubricating oil formulations on accumulated ash, this paper explores the effect of different lubricating oil formulations on the adaptability of GPF aftertreatment.

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2 Testing equipment and programmes

2.1 Test equipment

The test simulated the process of engine oil escaping and burning into the cylinder through the method of blending and discharging with the engine exhaust. Figure 1 is the engine bench and main test equipments, including oil mixing device, dynamometer, particle measuring instrument and so on.

Each durability test has a specific cGPF corresponding to it. By improving connection of the exhaust pipe installation, the systems are used for engine bench and vehicle emissions testing^[4].

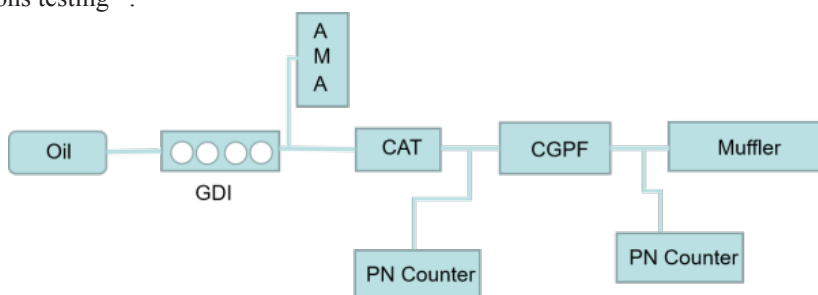


Fig .1. Main equipments of engine bench.

2.2 Test programme

In this paper, the accumulated ash is completed by the oil doping, which adds the specified concentration of lubricating oil to the fuel, so that the ash can be quickly accumulated onto the cGPF. The cGPF measures the accumulation of ash every 10 hours. These components are also installed on the test vehicle to test the emission control system. Tables 1 and 2 are the test engine and vehicle information, respectively.

Table 1. Test engine parameters.

Parameters	Parameters
Manufacturers	SAIC
Model	MGE
Capacity	2.0L
Fuel injection	Turbocharged DC
Rated power	162 kW
Rated torque	350 Nm

Table 2. Test Vehicle Information.

Parameters	Parameters
Manufacturers	SAIC MG GS
Model	SGE 15E4E
Capacity	1.5 L
Jet strategy	TGDI
Emission standards	National V emission standard
Initial emission control system	1CCC +IUFC

3 Fuel and lubricants

National V emission standard fuel was used in the test for the rapid accumulation of ash. Using fuel containing higher aromatics increases the soot generation rate. Tables 3 and 4 represent the composition of the two lubricants selected for the test, which are configured with III type of base oil. The main difference between the two is that the detergent system used is different: oil F based on the full calcium detergent system, and oil C based on the mixed Ca/Mg detergent system.

Table 3. Composition Lubricants C(a).

Property	Units	Content
Kv40	Mm ² /s	72.46
Kv100	Mm ² /s	12.21
Ca	ppm	1398
Mg	ppm	473
P	ppm	802
Zn	ppm	873
Mo	ppm	37

Table 3. Composition Lubricants F(b).

Property	Units	Content
Kv40	Mm ² /s	71.96
Kv100	Mm ² /s	12.13
Ca	ppm	2120
Mg	ppm	19
P	ppm	803
Zn	ppm	889
B	ppm	50
Mo	ppm	112

4 Test results

4.1 Filter mode conversion

It is well known that there are two kinds of filtering methods: bed filtration and cake filtration.^[5] At the initial stage of using cGPF the particles used bed filtration. After the particles can not penetrate into the hole continuously, the particles will gradually form the filter cake along the filter channel and the filter mode will be changed to filter cake filtration^[6]. Both models can effectively remove particles from the exhaust gas, but they have different effects. In terms of filtration efficiency, cake filtration is better than deep bed filtration. All filtration processes begin with deep bed filtration^[7].

After obtaining the universal characteristics, the three-stage aging conditions are selected as shown in Figure 6. A condition for 1 hour to simulate ash aging; B condition for 0.5 hour to simulate thermal aging; C condition for 0.5 hour to simulate soot ageing. Using the PEMS measurement equipment, the PN before and after GPF is measured to obtain the collection efficiency of GPF.

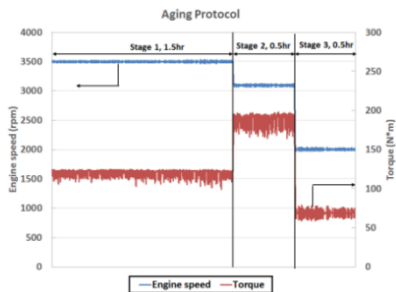


Fig. 2. Engine accelerated aging technology.

In figure 3, the amount of accumulated ash gradually increases with time, and the collection efficiency of GPF for oil F ash also increases rapidly, from the initial 83% to 96% after 10 hours, and then the growth rate gradually flattens. This is due to the accumulation of initial ash stratification, which enhances rapidly GPF's ability to intercept deposition, and the deep bed filtration mode gradually changes to filter cake filtration. The trapping efficiency will rapidly increase to about 95%. After that, the GPF trapping efficiency tended to be stable.

However, for oil C, its capture efficiency is unstable, gradually decreasing from the initial 93% to 80%, and then rapidly increasing to 94%. It may be due to the large amount of Mg element in the lubricating oil component, which will affect the initial composition of the main ash constituents CaO and P₂O₅, which in turn affects the GPF capture efficiency.

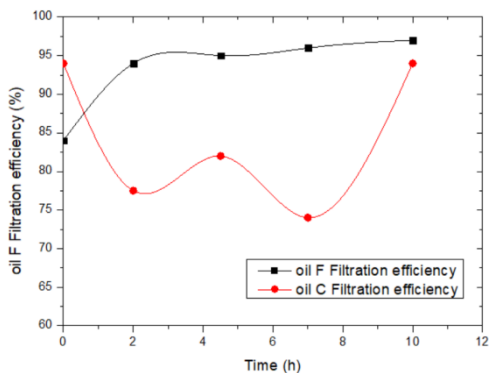


Fig. 3. The accumulated ash improves filtration efficiency (10 hours).

The GPF is weighed every 10 hours. As shown in Figure 4, the increase of oil F weight is obvious in the first 70 hours, while the GPF weight of oil C increases after 80h, and the total accumulated ash of 45g is reached after the 170h test. Combined with the difference in capture efficiency in Figure 3, it also shows that the accumulated ash amount of oil F is relatively stable at 2.2-2.8g per 10 hours. On the other hand, the accumulation of oil C is unstable per 10 hours, sometimes 3.4g and sometimes 1.6g, due to the influence of Mg.

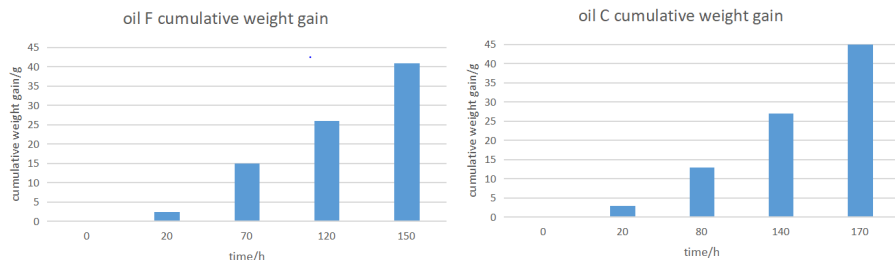


Fig. 4. Total ash accumulation process.

4.2 Vehicle emission and fuel consumption performance

cGPF requires regulatory requirements for particulate emissions to be met at the end of the test. Figure 5 plots the changes in particulate emissions (PN and PM) of oil F and oil C during the WLTC cycle of the test vehicle. The figure shows that the emission level of particulate matter is greatly reduced compared with the original vehicle without installed cGPF (marked "OEM"). As the filtration mode transitions from deep bed filtration to cake filtration, aging time and accumulated ash increase. The number of continuously generated particles decreases. Figure 5 shows National VI emission standard limits on the quantity and quality of particulate matter. The test results of both oils show that they meet the emission durability requirements, which are lower than the regulatory limit of 6.0×10^{11} . Comparing the PN value, the first 70h oil F has a higher trapping efficiency, and the oil C has a higher trapping efficiency after 70h, which corresponds to a lower PN value after GPF. 70h corresponds to 33% of the total accumulated ash.

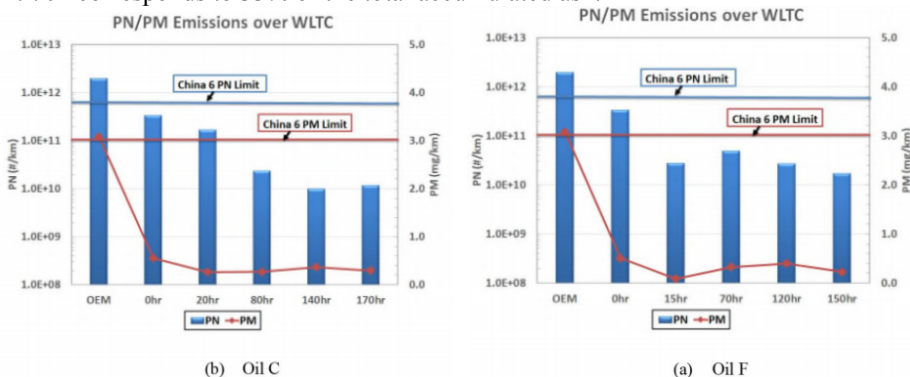


Fig. 5. PN and PM changes in the WLTC cycle.

From figure 6, the accumulated ash of 200000 km durable mileage has little effect on cGPF fuel consumption. Comparing two kinds of lubricating oil, the oil consumption value of oil F is slightly smaller than oil C in the whole process.

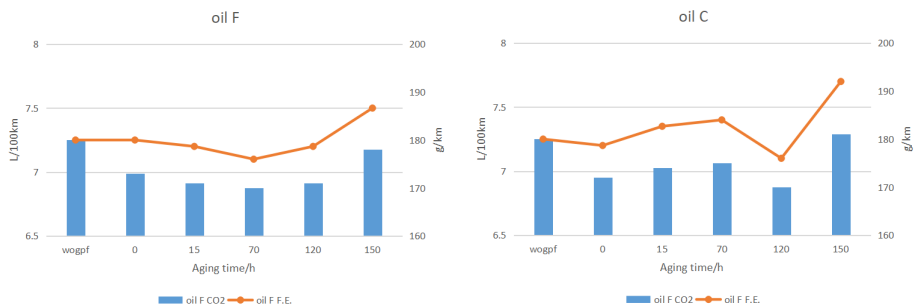


Fig. 6. WLTC Changes in fuel consumption.

4.3 Post-test analysis

After the durability test was completed, a series of comprehensive analyses were performed to evaluate the interaction of cGPF properties with the chemical properties of lubricants. This paper only introduces the CT scan results. When the ash enters the cGPF, it will first penetrate the hole wall and then gradually deposit along the hole wall until the end of the test.^[10] Unlike the soot, ash can not be regenerated^[11]. As a result the deposition of ash and its interaction with cGPF(including substrate and catalyst coatings) may have an impact on hardware performance and durability^[12]. CT scanning was performed on non-destructive microstructure analysis of cGPF samples. To investigate the deposition of ash within the filter channel, the ash height and channel diameter were measured.

The average ash height of the oil F on cGPF is less than that of the oil C as shown in figure 7. There is little difference in the channel diameter of the cGPF of the two oils. In order to capture the deposition distribution of ash in the channel, it was measured at the inlet, center and outlet of cGPF. The results are shown in Figure 8. For oil F, less ash is deposited in the front and middle of the cGPF, while more ash tends to deposit towards the outlet. In contrast, cGPF aged with oil C have a relatively uniform deposition distribution. However, the aging cGPF of both oils showed no sign of blockage in any passage from the entrance to the exit.

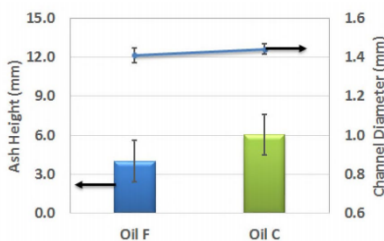


Fig. 7. CT scan of gray height and channel diameter.

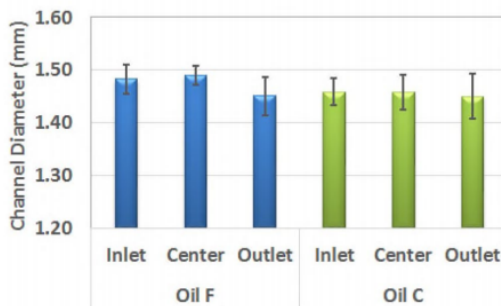


Fig. 8. CT scan to measure the statistical results of the entrance, center and exit channel diameters.

5 Conclusions

Based on two different components of lubricating oil, this paper analyzes the filtration efficiency, ash accumulation speed, vehicle WLTC emission, fuel consumption and CT scanning, and draws the following conclusions:

(1) The filtration efficiency of oil F will gradually reach 98%, and the filtration efficiency of oil C is unstable;

(2) Both types of lubricants can ensure that cGPF meet the emission and fuel consumption requirements of National VI emission standard. However, when the accumulated ash amount is less than 33%, the accumulated ash of oil F is faster, and the reduce of PN is obvious. When the accumulated ash is greater than 33%, the accumulation of oil C is faster, which accelerates the PN reduction;

(3) The average ash height of the oil F on cGPF is less than that of the oil C due to the final CT results;

(4) For oil F, less ash deposits occur in the front and middle of the cGPF, while more ash deposits lean toward the exit. In contrast, cGPF aged with oil C have a relatively uniform deposition distribution.

Finally, the candidate oil F based on the whole calcium detergent system, which tends to slow down the capture efficiency first and then slowly; the candidate oil C is based on a mixed Ca/Mg detergent system, which tends to slow down first and then quickly. The critical point is generally about 33% of the accumulated ash. Based on the GPF, the vehicle emission and fuel consumption can reach the National VI emission standard limits to meet the requirements of energy conservation and emission reduction.

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