Study on emission characteristics of biodiesel fuel for heavy diesel vehicles

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Abstract. This study uses the C-WTVC cycle to simulate the actual driving conditions of bus on the classic dynamometer to test the emission of vehicles with different fuels of Tier IV and V buses. The results showed that the NOx emission of Beijing VI diesel fuel blended with 5% biodiesel increased compared with the emission of pure diesel of Beijing VI, but the overall increase was not significant. The emission factors of CO, THC and PM the have been reduced. Heavy vehicles with Beijing-VI diesel fuel blended with 5% biodiesel did not change much in emissions and durability prior to endurance of 10,000 km.

1. Introduction

The prevention and control of atmospheric pollution has become one of the most important tasks in the current domestic environmental protection governance. As a major air pollution source, mobile source emissions have received increasing attention from the government and society. In mobile source emissions, heavy-duty diesel vehicles account for a large proportion of exhaust emissions and are the main sources of NOx and PM pollution. According to the statistics of 2014, the number of diesel vehicles only accounted for 14.1% of the total vehicle volume, but they contributed 69.2% of NOx emissions and 99% of particulate emissions from vehicle emissions. Studies have shown that the number of heavy vehicles in Shanghai only accounts for 5.5% of the total vehicle population, but the contribution rate of NOx and PM is as high as 65% and 56%. Therefore, controlling the exhaust emissions of heavy-duty diesel vehicles has become one of the research focuses of current atmospheric protection. Currently, there are many technologies for reducing the emissions of heavy-duty diesel vehicles on the market, but most of them are accomplished through the optimization of the engine structure or the addition of exhaust gas treatment devices, and less are accomplished through fuel technologies. However, through structural changes and the addition of post-processing methods to reduce emissions consume a large investment and a long-term return, cannot restrain emissions of pollution for a short time.

Biodiesel is an oil crop, and biodiesel is a methyl ester or ethyl ester fuel made from transesterification process using oil plants such as oil crops, wild oil plants and engineered microalgae, and animal fats, animal oils, and waste oils. Compared with traditional petrochemical diesel, biodiesel is an ideal diesel alternative fuel because of its high cetane number, low aromatic content, low volatility, and oxygen atom in fuel molecules. In this study, China National Vehicle Group 6 diesel fuel blended with a certain percentage (5%) of biodiesel was used as fuel to study its impact on heavy-duty diesel vehicle exhaust emissions.
2. Test vehicle and test fuel

2.1 Test vehicle
The test adopts two models, a total of six diesel buses, three are China IV, and three are China V. The test cars 1-3 are buses that meet the China IV emissions, and the test cars 4-6 are buses that meet the china V emissions.

| Item                                  | Model 1 | Model 1 |
|---------------------------------------|---------|---------|
| Vehicle type                          | Bus     | Bus     |
| Service quality (kg)                  | 11800   | 12780   |
| The maximum design total mass (kg)    | 17500   | 18000   |
| Engine Power (kW)                     | 228     | 228     |
| Engine Speed (rpm)                    | 2200    | 2200    |
| Emission stage                        | China IV| China V |

2.2 Test fuel
There are three types of fuels for the test: Beijing VI diesel, National V diesel, and Beijing VI diesel fuel blended with 5% catering waste oil.

3. Test equipment and test methods
The test equipment includes a chassis dynamometer and a full-flow exhaust gas detection device. The chassis dynamometer is an ECDM-72H heavy-duty drum produced by German MAHA: the wheelbase adjustment range is 3.2-8m, the load simulation range is 3.5-49t, and the maximum simulation speed is 130km/h. The full-flow exhaust gas exhaust equipment is a MEXA-7000 constant volume sampling analyzer manufactured by HORIBA. Includes a chemiluminescence analyzer (CLD) for NOx detection, a hydrogen flame analyzer (FID) for HC detection, a non-dispersive absorption analyzer (NDIR) for detection of CO and CO_2, a particle sampling device for detecting PM, and a microbalance between weighing and weighing, it can meet the testing requirements for emission standards in all phases of heavy-duty vehicle China IV, China V, and VI.

Six buses equipped with diesel engines were selected. Three vehicles in each phase of China IV and China V were used to compare the emissions of different fuels (China V, Beijing VI, and B5).

Due to the randomness of the bus driving in the city, the results of the road emission test are difficult to show enough contrast. Therefore, the use of the urban operating conditions in the C-WTVC cycle in the hub gantry part simulates the actual road conditions for testing. The C-WTVC urban operating condition cycle simulates the operating conditions of heavy-duty vehicles operating in urban road conditions. The operating time is 900 seconds, the total mileage is 5.73km, and the average speed is 22.92km/h. The maximum vehicle speed is 66.2km/h. C-WTVC idle speed, acceleration, acceleration and uniform speed in the urban working condition cycle are respectively 20%-30%, which is basically the same as the road condition when the actual bus runs and can meet the test requirements.

In order to minimize the errors caused by driving habits, the same driver was used for each test. Each test has 3 test cycles, taking the arithmetic mean of the results of the 3 test cycles as the test results.
4. Test results and discussion

4.1. NOx emissions

Figure 1 shows the results of NOx emissions from different types of fuel for test vehicles. From the emission results, it can be seen that there is no correlation between the emissions of NOx from the Beijing VI diesel and the China V diesel at different stages of emission, and the difference in the NOx emission factor is small. Therefore, it is possible to determine that Beijing VI diesel and China V diesel have little effect on vehicle NOx emissions.

When B5 biodiesel was used as a fuel, the test vehicles exhibited increased NOx emission factors. As the vehicles are operating in urban conditions, frequent start-stops and accelerations occur. When the vehicle starts or accelerates, the circulating fuel supply rises rapidly. However, due to the slow response of the diesel supercharger system to the electronically controlled fuel supply system, the intake air quantity is delayed, the air-fuel ratio in the cylinder is reduced, and the oxygen-rich environment where NOx is most likely to be generated is not achieved. As an oxygen-containing fuel, biodiesel can provide a certain amount of oxygen in the cylinder combustion chamber, which indirectly increases the air-fuel ratio and creates an oxygen-rich environment. At the same time, biodiesel has a higher calorific value and a longer ignition delay, which helps to increase the maximum combustion temperature and contributes to the formation of NOx.

After the test vehicle was operated for 5000 km, the NOx emission factor was increased. This is due to the fact that the vehicle is running on a long road and is fully inching and burning. Therefore, there is a small increase in NOx emissions compared to the initial mileage. The increase in the NOx emission factor after 10,000 km is small compared with 5000 km, and the vehicle operation is stable.
4.2. CO emissions

Figure 2 shows the results of CO emissions from different types of fuel for test vehicles. From the emission results, it can be seen that the CO produced by the test vehicle fueling China V diesel is more than the CO produced by burning Beijing VI diesel fuel. Beijing VI diesel has fewer polycyclic naphthenes than National V diesel, and vehicles using Beijing VI diesel have more complete combustion in the cylinder, so the amount of CO produced is less than that of vehicles using the China V diesel.

Comparing B5 diesel with Beijing VI diesel for CO emission factors, we can see from the results that the CO emission factor of the test vehicle using B5 diesel is small. CO is the result of incomplete combustion of fuel. Test vehicles often start and stop, accelerate and decelerate in the test cycle of urban operating conditions, and the instantaneous circulation of oil increases, resulting in a low oxygen content in the cylinder and prone to CO. As an oxygenated fuel, biodiesel can provide additional oxygen when the fuel is burned, making the fuel more complete and reducing CO emissions. And the increase of oxygen also reduces the possibility of CO2 being reduced to CO, thereby further reducing CO emissions.

After the test vehicle was operated for 5000km, the CO emission factor decreased. This is because the vehicle is fully burned in and the combustion is more complete, so CO emissions are slightly reduced compared to the initial mileage. After 10,000 km, CO emissions did not increase compared with 5000 km, and the vehicle operation was stable. The CO factor of the test vehicle 3 has increased. Considering that the fuel consumption and smoke are increased at the same time in the test, it is judged that the oil nozzle wears too much, resulting in an increase in the amount of oil compared to the initial mileage and thus an increase in the CO emission factor.
Figure 3. Comparison of CO emission factors of test vehicles

4.3. HC emissions

Figure 3 shows the HC emissions from different types of fuels used by the test vehicle. From the emission results, it can be seen that there is no corresponding relationship between the emissions of the Beijing V diesel and the China V diesel for the different stages of the emission of the engine, and the difference in the HC emission factor is relatively small. Therefore, the test vehicle fuel can be determined that Beijing VI diesel and China V diesel have little effect on vehicle HC emissions.

Comparing the impact of B5 diesel and Beijing VI diesel on HC emission factors, it can be found that the HC emission factor of vehicles using B5 diesel is smaller than that of Beijing VI diesel vehicles. HC is produced by incomplete combustion after fuel cracking. The test vehicle has many low speeds in the test cycle, the mixture is leaner and the temperature inside the cylinder is lower, which is likely to produce HC. Frequent start and stop conditions in the test cycle will result in an increase in the amount of oil circulating along the cycle, and the air-fuel ratio in the cylinder will be relatively low, and HC will also be easily generated. As an oxygenated fuel, biodiesel can provide additional oxygen when the fuel is burned, and the combustion is relatively complete, so that the HC chain after the fuel is cracked can be burned more completely, thereby reducing the HC emissions.

After the test vehicle was operated for 5000km, the HC emission factor decreased. This is due to the fact that the vehicle is fully burned in and the combustion is more complete, so the HC emissions are slightly reduced compared to the initial mileage. After 10000km, the HC emissions did not increase compared with 5000km, and the vehicle operation was stable.
4.4. PM emissions

Figure 4 shows the results of PM emissions from different types of fuel for test vehicles. From the emission results, it can be seen that for Beijing-VI diesel and China-V diesel, the emissions of Beijing VI diesel and China V diesel have opposite trends for different stages of emission of the engine. Considering the difference in the calibration strategy between the national IV diesel engine and the national V diesel engine, it cannot be judged the fuel difference is related to the result.

Comparing the impact of B5 diesel and Beijing VI diesel on PM emission factors, we can find that the CO emission factor of vehicles using B5 diesel is smaller than that of Beijing VI diesel vehicles. The main source of PM is the soot particles formed by the dehydrogenation of unburned diesel fuel, which is easy to generate when the air-fuel ratio of the diesel engine is relatively low. The test cycle used in the test vehicles is urban working conditions, and there are many start-stop conditions. Therefore, the cyclical fuel supply in the cylinder, low air-fuel ratio, and poor combustion make it very easy to generate PM. Biodiesel is an oxygenated fuel and its oxygen content is close to 10%. Provides extra oxygen during combustion, increases the air-fuel ratio in the cylinder, and makes combustion more efficient. Moreover, since the distribution of biodiesel in the cylinder is basically the same as that of Beijing VI diesel, it is possible to increase the oxygen content in the over-concentrated areas of oil and gas and improve the combustion. In summary, because biodiesel contains a certain amount of oxygen, it can improve in-cylinder combustion and reduce PM emissions.

After five test vehicles were operated for 5000km, the PM emission factor decreased. This is because the vehicle is fully burned in and the combustion is more complete, so PM emissions are slightly reduced compared to the initial mileage. After 10000km, the HC emissions did not increase compared with 5000km, and the vehicle operation was stable. The PM emission factor of the test vehicle 3 has increased.
Considering that CO increases at the same time in the test, it can be judged that the nozzle hole may increase, causing the oil volume to increase compared to the initial mileage and causing an increase in the PM emission factor.

![Graph showing PM emissions from China IV and V buses](image)

(a) Results of PM emissions from China IV buses

(b) Results of PM emissions from China V buses

**Figure 5.** Comparison of PM emission factors of test vehicles

5. Conclusion

1. There is no significant improvement in emissions from the China V diesel and Beijing VI diesel.
2. The NOx emission factor for vehicles fueled with 5% biodiesel has increased compared to the use of pure Beijing VI diesel.
3. For vehicles using Beijing VI diesel fuel blended with 5% biodiesel, the emission factors for PM, HC, and CO have been reduced to varying degrees compared to pure Beijing VI diesel.
4. After 10,000km-driving durable biodiesel-powered vehicles, there is no significant fluctuation in emission performance, and biodiesel has no adverse effect on vehicle fuel systems and after-treatment systems.

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