Research on Influence of Beijing-VI Diesel on Consumption and Emission Characteristics of Euro VI Diesel Bus

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Abstract. The characteristics of fuel consumption and emission from a euro VI diesel bus burning Beijing-VI diesel and China-V diesel were tested on heavy chassis dynamometer under C-WTVC testing cycle. The results indicated that the fuel consumption of Beijing-VI diesel is 1.12L/100km lower than China-V diesel and has the advantage of saving energy. A major emission factors were decreased, NOx emission reduced by 18%, PM emission reduced by 20%, CO and HC slightly decreased under C-WTVC testing cycle. Under city conditions, road condition and highway conditions, the NOx emission reduced by 25%, 18%, 16%.

1. Introduction
The possessing capacity of heavy-duty diesel vehicles in China accounts for 5% of gross of motor vehicles, yet they contribute 78% of nitrogen oxide emission and 82% of emission of particulate matters (PM), and the emission of exhaust fume has emerged as an important urban atmosphere pollutant source in China to directly undermine citizens' health ([1]). In the face of increasingly severe pollution, on the one hand, the manufacturers attempt to reduce emission of vehicle pollutants by adopting advanced post-processing technologies such as diesel particulate filter (DPF), selective catalyzing reduction (SCR), continuously regenerating diesel particulate filter (DOC+CDPF)([2]). On the other hand, the quality of diesel also has a important effect on emission of pollutants, so emission of exhaust fume by diesel vehicle can be reduced by improving fuel quality ([3]). On January 1, 2017, Beijing implements the fuel standard of stage fume by t fume by padjusts such indices as density, viscosity, flash point, etc. according to changes in refining process of diesel, and adds clearing agent in diesel to exercise further stricter control over the major environmental indices such as sulphur content and PAH in diesel, so it of far reaching importance for energy conservation and emission reduction.

The domestic and foreign scholars researched extensively the influence of diesel quality on the performance of diesel engine and diesel cars, in the hope of reducing emission ([4]). LU studied the effect of fuel characteristics on diesel engine burning at low temperature to find that the influence of cetane value of fuel on ignition delay period is large to influence emission of PM, while other characteristics of fuel do not have a large effect on combustion ([5]). Zhao Lei et al. experimented on China-III and China-IV diesel as well as Beijing-V diesel to find that the quality of diesel has a bearing upon fuel economy of diesel engine, and has an unobvious influence on emission of CO and HC, while has an obvious influence on emission of NO and PM([6]). Hu Zhi yuan et al. researched emission performance of China-IV buses burning diesel and B5 biological diesel on heavy-duty chassis dynamometer under CCBC cycle to find that the emission of THC and NOx for this bus burning B5 biological diesel increased, while emission of CO and PM reduced([7]). Wang Yan jun et al. adopted PEMS method and method of entire car chassis dynamometer to research the influence of different loads and testing conditions on measurement of emission factors for heavy-duty vehicle,
finding that the emission factors of gaseous pollutants measured by the two methods had good correlation, while the gap between emission factors for PM was up to about 50% ([8]). Current research is mostly focused on the influence of fuel quality on emission of China-III and China IV diesel engine, while little has been reported on emission of Euro-eldiediesel vehicle with advanced post processing technology applied. Heavy-duty chassis dynamometer can test on diesel vehicle in specific environment and avoid the drawbacks of poor repetitiveness and weak representativeness of engine bed test in actual road tests, so it has become an important method for domestic and foreign scholars to research performance and emission of diesel vehicle. The paper takes buses meeting Euro emission standard as test vehicle to research the oil consumption and pollutant emission of Beijing-ivdiesel and China-andiesel in condition of C-WTVC cycle on heavy-duty chassis dynamometer, in an effort to provide a certain reference frame for learning the influence of quality of Beijing-VI diesel on energy dissipation and emission of diesel vehicle and further popularization across the whole China.

2. Test Equipment and Scheme

2.1. Test equipment
This test is carried out on the four chassis dynamometer, the chassis dynamometer is produced by Germany MAHA Group, which can meet the test requirements of 4×4, 6×6, 8×8 and other driving types. It has sensitive control system and electronic inertia simulation device, and can simulate up to 35t truck weight and 2500kg to 60000kg of vehicle inertia. Measurements of pollutant emissions adopt CVS i60, AMA i60 and PSS i60 devices complying with the requirements of 2005/55 / EC. CVS i60 controls the temperature of the CVS sampling system, the acquisition capacity of the dilution tunnel, and achieve constant volume sampling. AMA i60 exhaust measurement system can be carried out during the operation of the vehicle pollutant transient measurement, with non-spectral infrared analysis of CO, measurement of hydrogen flame ion for THC, measurement of non-spectral UV chemiluminescence for NOx. PSSi60 mainly controls the particulate matter collection system so that the sampling conditions of the particles are guaranteed to be within the limits prescribed by the regulations.

2.2. Test prototype and test program
The test sample is a heavy-duty diesel city bus, its emission standard meets the Euro VI emission standard, and its main technical parameters are shown in table 1.

| Subjects                  | Parameters                        |
|---------------------------|-----------------------------------|
| Vehicle type              | City Bus                          |
| Total quality             | 11800kg                           |
| Engine type               | Turbocharged Intercooler Diesel Engine |
| Displacement              | 8.4L                              |
| Rated speed               | 2200r/mim                         |
| Maximum power             | 210kW                             |
| Maximum torque            | 1200N·m                           |
| Emission grade            | Euro VI                           |
| Oil supply system         | high-pressure common-rail         |
| Post processing system    | SCR+DPF+DOC                       |

The measurement is in accordance with GB27840-2011 (Fuel consumption test methods for heavy-duty commercial vehicles) and the test conditions is C-WTVC cycle. C-WTVC cycle are based on the WTVC cycle, according to China's actual road conditions to adjust the acceleration and deceleration of the formation of the test cycle. The whole test condition consists of urban conditions, road conditions and high speed conditions. Figure 1 is the test site.
2.3. Fuel characteristics

The test used 0# Beijing-VI car-use diesel and 0# China-V car-use diesel, whose major physical and chemical indices are as shown in Table 2. The two kinds of diesel fuel samples are tested by all items test of Shanghai SGS test center.

**Table 2. Major physical and chemical characteristics of diesel**

| Subjects                          | 0# Beijing-VI diesel | 0# China-V diesel |
|-----------------------------------|----------------------|------------------|
| Total insolubles mg/100ml         | 0.7                  | 2.5              |
| Ash content %                     | 0.001                | 0.01             |
| 10% steam excess carbon %         | 0.1                  | 0.3              |
| PAHs %                            | 0.8                  | 11               |
| Cetane number                     | 54.2                 | 52.2             |
| Sulfide mg/kg                     | 2.5                  | 3.6              |
| 20°C density g/cm³                | 0.831                | 0.834            |
| 20°C kinematic viscosity mm²/s    | 4.2                  | 4.1              |
| Flash point °C                    | 68                   | 69               |

The table shows that the major physical and chemical characteristics of the two kinds of diesel all meet relevant standards. The main differences were as follows. The total insolubles content was 2.5 mg/100ml in the China V diesel and 0.7 mg/100ml in the Beijing VI diesel. The ash was 0.01% and 0.001%, respectively. The 10% steam excess carbon was 0.3%m/m and 0.1%m/m, respectively. The PAH content was 11%m/m and 0.8%m/m, respectively.

3. Test result and analysis

3.1. Driving curve

Figure 2 compares set velocity of test vehicle in standard condition and actual driving velocity in burning the two kinds of diesel, finding that the two testing velocities are well repetitive, highly keep in line with set velocity, and well follow velocity in condition of C-WTVC cycle.

![Figure 1. Test site](image)

![Figure 2. Testing velocity and target velocity](image)
The running time of the whole test is 1800 s, including 900 s for urban working condition, 468 s for road condition, 432 s for high speed condition, and the running distance is 20.51 km. Under C-WTVC condition, the idling time is 186s, idling proportion is 10.3%, maximal speed is 87.8km/h, average velocity is 40.1km/h, maximal acceleration is 0.92m/s$^2$, maximal deceleration is 1.03 m/s$^2$.

3.2. Emission factor of pollutant

Able to reflect actual emission level of vehicle, emission factor is an important reference for researching pollutants. Figure 3 and figure 4 are emission factors of pollutants for the test vehicle burning China-Ⅴ diesel and Beijing-Ⅵ diesel under condition of C-WTVC.

![Figure 3. Emission factors of different fuel](image)

**Figure 3.** Emission factors of different fuel

![Figure 4. NOx emission factors of different fuel](image)

**Figure 4.** NOx emission factors of different fuel

It can be seen from the test results of figs. 3 and 4 that compared with the burning of China-d diesel, the emission factors of four main pollutants of the diesel engine fueled with Beijing-Ⅵ diesel is decreased. Among them, HC emission factor, CO emission factor, NOx emission factor and PM emission factor are respectively reduced by 0.001 g / km, 0.001 g / km, 0. 065 g / km and 0.004 g / km, and the decreasing ranges of NOx emission factor and PM emission factor are separately about 18% and 25%. The reduction of NOx and PM is mainly affected by the physical and chemical properties of fuel, the cetane number is the most important parameter of the exothermic moment, which has a significant effect on ignition delay period, it is also conducive to improve cetane value and improve fuel fire, so that the combustion is relatively full using and the incomplete combustion products is reduced([9], [10]). Diesel particulate matter is mainly composed of carbon soot particles, sulphate, incomplete combustion fuel, oil and intermediate products; and diesel fuel sulfate and gaseous SO$_2$ emissions are increased linearly.

To further analyze the differences in emission factors of pollutants for different fuels in different characteristic mileages, the emission factors for different stages in whole C-WTVC condition were researched. Table 3 shows emission factors for diesel vehicle burning China-Ⅰ diesel and Beijing-diesel in C-WTVC cycling under conditions of town, highway and high speed.
Table 3. Emission factors in different conditions

| emission | urban condition | road condition | high speed condition |
|----------|----------------|----------------|---------------------|
|          | China-Ⅴ       | Beijing-Ⅵ     | China-Ⅴ             | Beijing-Ⅵ          |
| HC/10⁶   | 4.21           | 4.07           | 3.98                | 3.65               |
| CO/10⁶   | 0.56           | 0.40           | 0.64                | 0.53               |
| NOx/10⁶  | 6.70           | 4.97           | 3.32                | 2.71               |

The result shows that when the diesel vehicle drove in different conditions, the emission of HC and CO was not largely different, with burning Beijing diesel emitting slightly less HC and CO than burning China-Ⅴ diesel. The test condition has a larger effect on NOx emission of vehicle. The emission of diesel vehicle burning China-Ⅴ diesel is 6.7×10⁶, 3.32×10⁶ in highway condition and 1.51×10⁶ in high speed condition. The emission of diesel vehicle burning Beijing diesel is 4.97×10⁶, 2.71×10⁶ in highway condition, 1.26×10⁶ in high speed condition, showing a decrease of about 25% in town condition, a decrease of 18% in highway condition, and a decrease of 16% in high speed condition. In town condition, due to frequent accelerating and decelerating of vehicle, the diesel engine is in the state of low rotation rate and high load for long, under which state, the average air-fuel ratio of combustible mixture is on the small side, and the highest combustion temperature rises. High temperature, oxygen enrichment and endurance period of reaction are key factors influencing generation of nitrogen oxide, so emission of NOx is far higher than in that in highway condition and high speed condition. Although the temperature in air cylinder is low in high speed condition, yet the reaction time to generate nitrogen oxide provided by higher rotation rate decreases, leading to reduction of NOx emission factor ([11]).

3.3. Transient emission of pollutants

Figures 5-7 are real time emission curve of HC, CO and NOx for two kinds of diesel burnt by diesel vehicle. It is observed from figure 5 that the instantaneous emission of CO for Euro diesel vehicle has dropped to a low level, that for China diesel fluctuates around 0.6×10⁶, and Beijing diesel fluctuates around 0.2×10⁶. The CO emission of Beijing diesel reduces to some extent relative to China diesel.

Figure 5. Instantaneous emission of CO

Figure 6. Instantaneous emission of HC
It is observed from figure 6 that the emission trends of different fuels burnt by diesel vehicle are the same. The HC of China-Ⅴ diesel fluctuates around $4.1 \times 10^{-6}$, and the HC of Beijing-Ⅵ diesel fluctuates around $4 \times 10^{-6}$, which is a small decrease. As general control level of emission by Euro-Ⅵ diesel vehicle is high, plus the influence of interior calibration in engine and the ingredients of background air in the environment, the change in CO and HC is negligible.

It is observed from figure 7 that the NOx emission diesel vehicle burning Beijing-Ⅵ diesel reduces significantly. The highest emission concentration for diesel vehicle burning China-Ⅴ diesel is up to $26.1 \times 10^{-6}$, and the highest emission in burning Beijing-Ⅵ diesel is $11.1 \times 10^{-6}$. The average velocity in high speed condition is far higher than that in low speed condition. The instantaneous emission rates of NOx are not largely different, with emission far lower than that in city condition and highway condition. Instantaneous concentration of NOx is remarkably related to service condition of vehicle. Within the first 900s of the cycle, the vehicle is in town condition, with average velocity of 22.9km/h, maximal acceleration of 0.917m/s², and maximal deceleration of 1.033m/s². In city condition, the vehicle often accelerates or accelerates rapidly, so rotation rate of engine is low and load is large. When the vehicle accelerates, the augmentation fuel charge reduces air-fuel ratio of combustible mixture, increases combustion temperature and combustion pressure, and raises emission rate of NOx.

When vehicle decelerates or idles, the fuel charge of diesel engine is reduced, thereby decreasing emission rate of NOx. So the city condition sees large fluctuation in emission of NOx. Compared with Ⅴ diesel, the emission of NOx in burning Beijing-Ⅵ diesel all reduces to a certain extent in the three conditions. This is mainly because China-Ⅴ diesel has lower cetane value than Beijing-Ⅵ diesel, leading to increase of ignition delay period, increase of heat release rate, increase of premixed combustion capacity, decrease of diffuse combustion capacity, and increase of NOx emission.

3.4 Fuel consumption

The fuel consumption for combustion-use China-Ⅴ diesel and Beijing-Ⅵ diesel by diesel vehicle was measured based on C-WTVC condition, with measurement result as shown in table 4.

|          | urban conditions | road conditions | high speed conditions | Comprehensive |
|----------|------------------|----------------|-----------------------|---------------|
| China-Ⅴ diesel L/100km | 36.83            | 27.55          | 20.26                 | 27.52         |
| Beijing-Ⅵ diesel L/100km | 35.76            | 26.21          | 19.48                 | 26.40         |

The table above shows that the fuel consumption in town condition is the largest, which is caused by constant accelerating and decelerating of vehicle. In town condition, the fuel consumption of China-b is 36.83L/100km, and that for Beijing-Ⅵ is 35.76 L/100km. In highway condition, the fuel
consumption of China-3 is the 27.55 L/100km, and fuel consumption of Beijing-Ⅵ is 26.21 L/100km; in highway condition and high speed condition, the fuel consumption of China-h is 20.26L/100km, and that for Beijing-Ⅵ is 19.48; in the entire condition, the fuel consumption of China-Ⅴ is 27.52 L/100km, and fuel consumption of Beijing-Ⅵ is 26.40 L/100km, reducing by 1.12 L/100km, which is mainly largely related to cetane value of diesel. The higher the cetane value is, the higher the thermal efficiency is, the better the ignition performance, the more adequate the combustion is, hence lowering fuel consumption rate. With fuel consumption slightly lower than China-Ⅴ oil product, the Beijing-Ⅵ oil product has certain advantages in energy conservation.

4. Conclusions

This study tested the characteristics of fuel consumption and emission from a euro Ⅵ diesel bus burning Beijing-Ⅵ diesel and China-ing Beijing-Ⅵ diesel and consumption and emission from a euro Ⅵ diesel bus better the ignition performance, Compared with burning China-e diesel, the emission factor of pollutants for Euro-Ⅵ heavy-duty diesel vehicle burning Beijing-Ⅵ diesel is lower, NOx reduced by about 18%, PM reduced by about 20%, while CO and HC did not reduce significantly. In the course of instantaneous emission in C-WTVC condition, CO emission in burning China-diesel was about 0.6×10⁻⁶, HC emission was about 4.1×10⁻⁶. The CO emission in burning Beijing-diesel was about 0.2×10⁻⁶, and HC emission was about 4×10⁻⁶. The highest emission concentration for burning China-g diesel in city condition was up to 26.1×10⁻⁶, and the highest emission of combustion-use Beijing-Ⅵ diesel was up to 11.1ppm. The average velocity in high speed condition was far higher than that in low speed condition. The instantaneous emission rates of NOx were not largely different, with emission far lower than that in city condition and highway condition. Compared with burning China-b diesel, the consumption of Beijing-n diesel by diesel vehicle reduced by 1.12 L/100km, pointing to satisfactory economy.

5. References

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