Research on Emission Standards and Control Technology of Heavy Commercial Diesel Vehicles

Liu Xiaomin1,a, Wang Zhaoming1, Li Yezhen2, Liu Qifeng1
1College of Applied Technology, Jilin University, Changchun, Jilin, China
2Faw Automobile Sales Company, Changchun, Jilin, China
aemail: lxmin919@jlu.edu.cn

Abstract: More than 70% of the pollutants produced by heavy commercial diesel vehicles are from exhaust, which contains a large number of harmful substances. These substances are discharged into the air with vehicle exhaust, polluting the environment. In addition, the emission height of automobile exhaust is mainly between 0.3 meters and 2 meters, which is exactly the breathing range of human body, thus posing a threat to human health. At present, China has improved the management of exhaust emission testing of heavy commercial diesel engines, and the emission standard has been gradually raised from the national V standard to the national VI standard. This paper mainly expounds the hazards of different pollutants, studies on the national emission standards and control technologies, and provides references for the related industry research.

1. Introduction
The main objectives of Chinese 14th five-year Plan are to achieve new progress in ecological civilization construction, continuous improvement of ecological environment and living environment, and continuous reduction of pollutant discharge. But with the sharp increase in the number of cars, traffic jams are common. The automobile exhaust brought by so many vehicles is harmful. Therefore, China attaches great importance to control the urban environmental pollution caused by vehicle exhaust emissions.

Because of its high compression ratio, diesel engine has high fuel efficiency, good fuel economy, power performance and durability. Diesel engines are widely used in high-power vehicles such as large passenger cars and large trucks. According to statistics, from 2012 to 2017, the national diesel truck ownership showed an overall growth trend. It shows that the number of diesel trucks in China increased from 14.272 million in 2012 to 16.909 million in 2017, with an average annual growth rate of 3.45%. While heavy diesel vehicles bring economic benefits, there are also cases of environmental pollution caused by emissions. Therefore, China has formulated automobile emission regulations to control the emission of pollutants from motor vehicles.

2. Main components and hazards of exhaust gas of heavy diesel vehicles

2.1 Harm of exhaust gas to human body
Vehicle exhaust contains about 150 to 200 different compounds. Although diesel vehicle exhaust contains less HC, CO and HC than gasoline vehicle, but the NOx and PM emissions are much higher than gasoline vehicle. NOx and PM do great harm to human health. The main components of exhaust
gas and their harm to human body are shown in Table 1.

| Pollutant composition | Principal component | Harms to human body |
|-----------------------|---------------------|---------------------|
| NOx                   | NO N0₂              | It is harmful to the respiratory system. Exposure to NO₃ at a concentration of 9.4 mg/m³ for 10 minutes can cause respiratory dysfunction. |
| PM                    | The compositions are various, and the carbon particles produced by pyrolysis are the main compositions. | It causes chronic lung disease and can even cause cancer in people. It has a strong adsorption capacity. It can adsorb a variety of metal dust, and pathogenic microorganisms, etc. |
| HC                    | It is the pyrolysis product, mainly composed of benzene, butadiene, aldehydes and polycyclic aromatic hydrocarbons. | The most prominent harm to human body is to stimulate the eyes and the mucosa of the upper respiratory tract, causing eye redness, swelling and pharyngitis. |

2.2 Analysis of pollutant generation mechanism and its impact on the environment

The main cause of NOx is high temperature. It is one of the key and difficult points of diesel emission control. When the temperature in the cylinder is too high (generally over 1600°C), the inactive N₂ in the air becomes active. The N atoms are separated to react with oxygen to form NO and NO₂. Among which the content of NO is relatively high. The chemical reaction equation is as follows:

\[
N₂+2O \rightarrow 2NO \\
N+O \rightarrow NO \\
N₂+2O₂ \rightarrow 2NO₂
\]  

The factors influencing the production of NOx are temperature, O₂ concentration and reaction time. The higher the oxygen concentration is, the longer the chemical reaction time is, and the higher the temperature is, the more NOx are generated, which will seriously pollute the environment.

3. Comparative analysis of National VI with National V standard

The national VI emission testing items have been changed. New testing items have been added to national VI standard and higher requirements have been put forward for pollutant emission limits. It includes gaseous pollutants from exhaust, particulate matter quality and particle quantity. Table 2 shows the limits of pollutants discharged under three different national standards. The emission limits of CO, THC, NMHC, NOX and PM in phase B of national VI are 50%, 50%, 49%, 42% and 33%. Figure 1 shows the strictness of the three national standards on exhaust emission control. The lower the value, the more stringent the emission limits. It can be seen from Figure 1 that the National VI standard is very strict.

| Pollutants | National-V mg/km | National-VIa mg/km | National-VIb mg/km |
|------------|------------------|--------------------|--------------------|
| CO         | 740              | 1000               | 740                |
| THC        | 160              | 80                 |                    |
| NMHC       | 105              | 55                 |                    |
| NOx        | 280              | 82                 | 50                 |
| N₂O        | 30               | 30                 |                    |
| PM         | 4.5              | 4.5                | 3                  |
As one of the most advanced emission standards in the world, national VI standard is a big change in the whole industry. In June 2019, FAW took the lead in launching 17 Types of National Six vehicles, including tractors, trucks, dump trucks, special vehicles and light trucks. This shows that the implementation of national VI standards is feasible and meets the market’s demand.

4. Exhaust gas control technology of heavy commercial vehicles under national VI

4.1 Adjustment scheme for major components of heavy commercial diesel vehicles

Exhaust purification of heavy-duty diesel engines is mainly aimed at NOx and harmful particles with large emissions. Diesel vehicles are transferred from national V to national VI b through national VI a, and WLTC cycle is adopted to replace NEDC cycle for pollutant emission test. NOx and PM need to be reduced by 63% and 33%.

Under the national VI standard, the settings of the engine, electronic control system, HC injection system, urea injection system and rear processor of heavy-duty diesel vehicles are greatly changed, as shown in table3.

| project                | National V standards                                      | National VI standards                      |
|------------------------|----------------------------------------------------------|-------------------------------------------|
| engine                 | Mechanical release valve supercharger                     | Electric control supercharger (above 11L)  |
|                        | Without EGR                                              | Mechanical release valve supercharger      |
|                        | 1600 bar common rail multiple                            | EGR+ throttle system                      |
|                        |                                                          | 2000 bar common rail                      |
| Electronic control system | Control strategy based on MAP The five OBD              | New sensor Model-based control strategy    |
|                        |                                                          | Country OBD upgrade                       |
| Urea injection system  | Have                                                     | Have (Add urea mixers)                    |
| Post processor         | SCR                                                      | DOC+DPF+SCR+ASC                           |

4.2 Hardware composition of National VI diesel engines

The main electronic control hardware of the sixth diesel engine is composed of supercharger, EGR valve, throttle valve, intake temperature and pressure sensor, etc.

The exhaust gas from the engine flows into the supercharger and uses the exhaust energy to drive the supercharger to work. Part of the exhaust gas passes through the EGR control valve and flows back into the engine for combustion under the detection of the exhaust Venturi flowmeter. EGR control technology can effectively reduce the maximum temperature of the cylinder, thus reducing NOx production.
4.3 Hardware of diesel reprocessing system of National VI

The hardware of the reprocessing system of national VI diesel engines is constituted by DOC, DPF, SCR, ASC, exhaust temperature sensor, PM sensor, differential pressure sensor, HC injection system, and gas-driven urea system. The main function is to reduce engine emissions to meet regulatory requirements.

DOC system is mainly composed of carrier, catalyst and sensor. It can effectively reduce CO and HC emissions, but also can burn off some of the particles in the exhaust. The PM reduction rate is more than 10%-30%.

The main function of DPF is to collect the soot particles and other particles in diesel vehicle exhaust to purify the exhaust gas. The soot particles captured by DPF are actively or passively regenerated and burned inside the carrier into a small amount of ash. DPF diesel particle collector is an active combustion regeneration system and oxidation catalytic converter, which can effectively reduce PM with a reduction ratio of 80%-95%. DPF is made of porous wall flow ceramic material and coated with noble metal coating. It is divided into four parts, including packaging, clamp, carrier and liner.

SCR is mainly used to treat NOx in exhaust. In the emission regulations of national VI standard, stricter requirements have been made for NOx emission. The limit value of NOx has been reduced from 3.5g/ KWH to 1.2g/ KWH, which requires the SCR system to be able to carry out more strict and accurate control.

The chemical reaction equations of each system are shown in table 4.

| Chemical equations of each system |
|----------------------------------|
| **DOC** | **DPF** | **SCR** |
| 2NO+O₂→2NO₂ | C+N₀₂→CO+NO | 4NH₃+4NO+O₂→4N₂+6H₂O |
| 4HC+3O₂→2CO₂+2H₂O | (300-450℃) | 2NH₃+NO+NO₂→2N₂+3H₂O |
| 2CO+O₂→2CO₂ | 2C+O₂→2CO(>500℃) | 8NH₃+6NO₂→7N₂+12H₂O |

5. Conclusions

Heavy commercial diesel vehicles not only bring economic benefits to us, but also pollute the environment and bring health and safety risks to our life. China, in particular, has adopted the strictest national VI standard. In view of this standard, automobile enterprises adopt effective emission control technology means to reduce the harmful gas emitted by vehicles from the root. With the joint efforts of all of us, the Chinese 14th five-year Plan’s targets "new progress in ecological civilization construction, continuous improvement of ecological environment and living environment, and continuous reduction of pollutant emission" will be achieved within a short time!
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