

Research on real-driving emissions of heavy tractor under different loads

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Abstract. The actual road diesel emissions of heavy-duty vehicle is very high, which has been a concern around the world. In 2018, Chinese government promulgated the "China VI" regulations containing real-driving emission test requirements and limits, requiring vehicle manufacturers to effectively control vehicle emissions to meet the requirements of China VI. This article takes a heavy-duty tractor equipped with a "China VI" engine as the research object, and performs actual road emission tests after loading 10%, 25%, 50%, 75%, and 100% respectively. The results show that NOx emissions are higher at low loads and PN emissions are higher at high loads, and CO emissions are not sensitive to load changes.

1 Introduction

On July 3, 2018, the State Council issued the "Three-year Action Plan to Win the Blue Sky Defense War", calling for the fight against pollution of diesel trucks, formulating action plans for the fight against pollution of diesel trucks, and coordinating the management of fuel, roads, and vehicles to ensure that diesel vehicle pollution is reduced. It shows that government departments attach great importance to the actual emissions of diesel vehicles. China VI regulations changed the requirements for real-driving emission boundaries in National V regulations. The main differences between the actual emission boundary of National VI and the actual emission boundary of National V are shown in the following table. The Phase 6 PEMS test load range is extended to 10% -100%. The expansion of the test load range will have a significant impact on the real- emissions . At present, the OEMs lack corresponding development experience in this regard. This article tests the real-driving emissions of the PEMS cycle of a heavy-duty tractor in a country six platform under different loads. In this paper, the actual road emissions of the PEMS cycle of a heavy-duty tractor on a country six platform under different loads were tested accordingly.

Table 1. Comparison of PEMS requirements in different emission stages.

Item	China V	China VI b
Temperature range	2~38°C	-7~38°C

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Altitude range	<1000m	<2400m
Load range	50%~100%	10%~100%

According to relevant tests, it is found that the distribution of the PEMS cycle operating point of the actual road required by the national six regulations and the engine's WHTC cycle operating point have a large difference. As shown in the following figure, the development of the engine bench calibration During the process, the emissions and fuel consumption of WHTC were balanced and optimized, but under the actual road PEMS cycle conditions, there are still many high-risk conditions at the point of discharge. This also requires us to pay attention to the rectification during the development of the National Sixth Project. Relevant work on the development and calibration of actual road emissions of vehicles, otherwise there will be a large risk of non-compliance in actual road emissions of vehicles in use. Actual road emissions calibration development will have a profound impact on the sustainable development of the company's products and brand power.

aracteristics of oil refining process in China, FCC gasoline occupies the leading position, accounting for about 70%~85%^[1-2].

2 Test device and method

2.1 Test equipment

The test vehicle was a heavy tractor of the N3 category, with a maximum total mass of 42,000 kg. The vehicle is equipped with a high-pressure common rail diesel engine with a displacement of 7.7L and adopts an SCR + DOC + DPF aftertreatment device. The test emission test equipment used OBS-ONE-G12 vehicle emission analysis system produced by HORIBA. Test environment average temperature 11 °C, average atmospheric pressure 102.2kPa, average environmental humidity 66.3%.

The test was performed in accordance with the requirements of Appendix K of the GB17691-2018 regulation. The vehicles were loaded with 10%, 25%, 50%, 75%, and 100% loads, respectively, and then the PEMS test cycle was collected and relevant data was collected to complete the actual roads with different loading Emission test, analysis and discussion of test data.

Table 1. Test road ratio.

Item	Load 10%	Load 25%	Load 50%	Loaf 75%	Load 100%
Correlation coefficient of fuel consumption (r2)	0.9321	0.9832	0.9856	0.9849	0.9843
Urban proportion (%)	20.6	20.4	20.3	19.5	22.4
Suburban ratio (%)	25	24.1	24.8	25.1	24.5
High speed ratio (%)	54.4	55.5	54.9	55.4	53.1
WHTC cycle work (multiple)	5.88	8.07	7.91	7.28	6.6

3 Comparison and analysis of test

3.1 Test working condition distribution analysis

The distribution of the operating conditions of the engine with 10% load is shown in the figure 1:

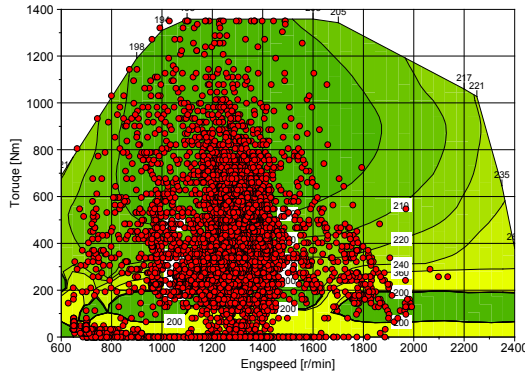


Fig. 1. Operating point distribution at 10% load.

The distribution of operating conditions of the engine loaded with 25% load is shown in the figure 2:

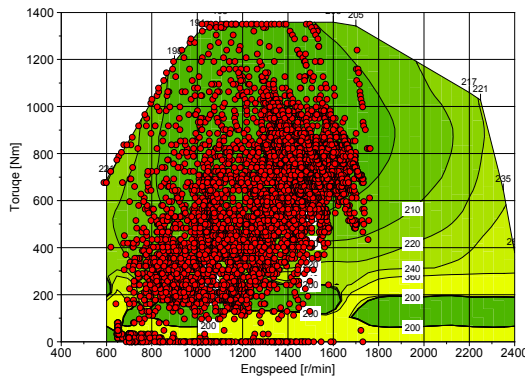


Fig. 2. Operating point distribution at 25% load.

As can be seen in the figure 2, most of the operating conditions of the engine loaded with 25% load are concentrated between 1000rpm ~ 1600rpm, and the operating conditions below 200Nm are relatively rare. The operating conditions point basically covers all areas of the operating conditions, The maximum speed of the engine is 1800rpm, and the maximum torque of the engine is 1350Nm.

The distribution of the operating conditions of the engine with 50% load is shown in the figure 3:

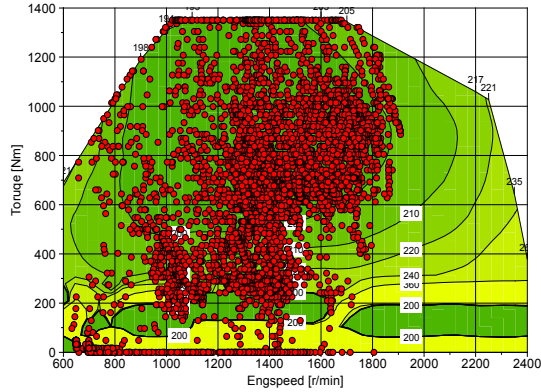


Fig. 3. Operating point distribution at 50% load.

As can be seen in the figure 3, most of the operating conditions of the engine loaded with 50% load are concentrated between 1000rpm ~ 1800rpm, and the operating conditions below 200Nm are relatively rare. The operating conditions point basically covers all areas of the engine operating conditions. The overall distribution of operating conditions is more uniform. The maximum speed of the engine is 1900 rpm, and the maximum torque of the engine is 1350 Nm.

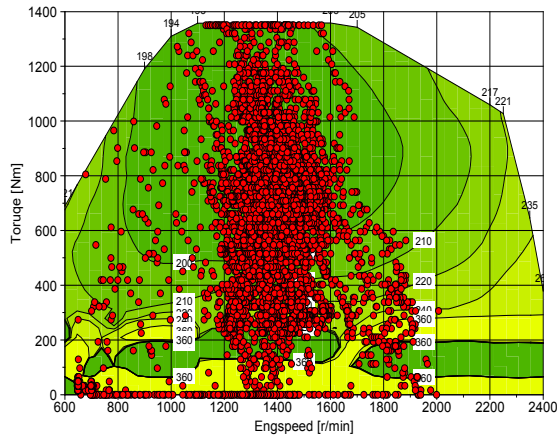


Fig. 4. Operating point distribution at 75% load.

As can be seen in the figure 4, most of the operating conditions of the engine loaded with 75% load are concentrated between 1200rpm ~ 1600rpm, and the operating conditions below 200Nm are relatively rare. The operating conditions point basically covers all areas of the operating conditions. The overall distribution of operating conditions is more uniform. The maximum speed of the engine is 2000 rpm and the maximum torque of the engine is 1350 Nm.

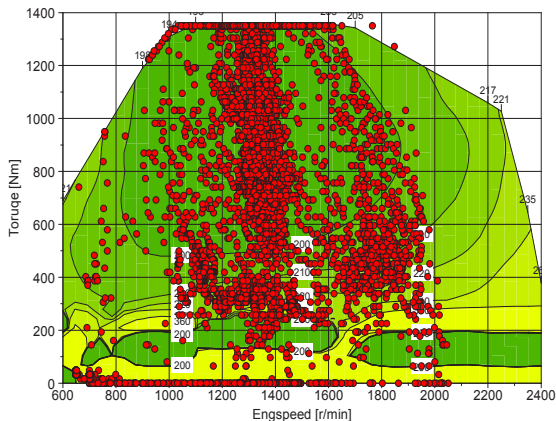


Fig. 5. Operating point distribution at 100% load.

As can be seen in the figure 5, most of the operating conditions of the engine loaded with 100% load are concentrated between 1200rpm ~ 1800rpm, and the operating conditions below 200Nm are relatively rare. The operating conditions point basically covers all areas of the operating conditions. The overall distribution of operating conditions is more uniform. The maximum speed of the engine is 2050 rpm and the maximum torque of the engine is 1350 Nm.

The distribution of engine operating conditions depends on the speed ratio of the gearbox. For manual gearboxes, the driver's shifting speed will affect the frequency distribution of the operating speed range of operating conditions. As can be seen from the test data This model has an engine speed limit of 2050 rpm and a maximum engine torque of 1350 Nm.

3.2 Test Analysis of emission test results

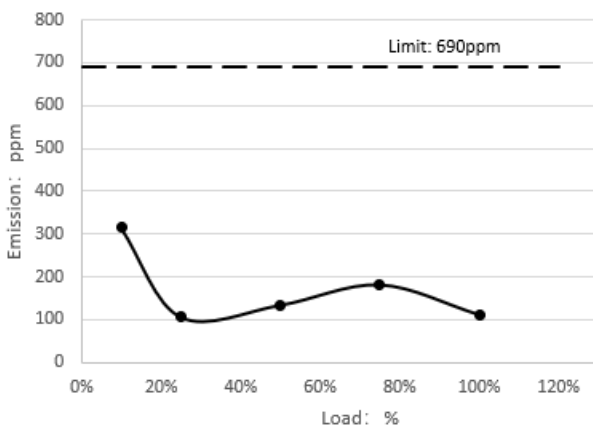


Fig. 6. NOx emissions under different loads.

It can be seen from Figure 5 that NOx emissions show a non-linear change with loading changes. The 10% loading of NOx emissions is the highest, and the 10% loading is also the minimum loading boundary required by regulations.

The vehicle's NOx emissions are determined by the original emissions of the engine itself and the NOx conversion efficiency in the SCR aftertreatment. The reduction space of the engine's original exhaust is small, and the NOx conversion efficiency of the SCR post-

treatment is very high, and under appropriate conditions, the conversion efficiency can reach more than 95%. The main influencing factors of SCR conversion efficiency are the exhaust temperature of the engine, the amount of urea injected and the degree of mixing. The hardware of the mixer on the vehicle has been solidified, the urea injection temperature is set, and the exhaust temperature of the engine has become the main factor affecting the vehicle's NOX emissions. The following compares and analyzes the exhaust temperature of the tail pipe of the vehicle with 10%, 25%, 50%, 75%, and 100% loads:

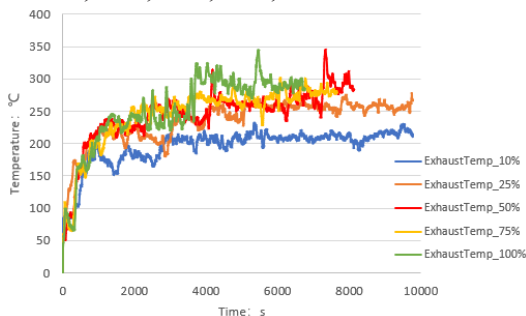


Fig. 7. Comparison of exhaust temperature under different loads.

It can be seen from the figure above that the exhaust temperature level of 10% loading is the lowest under several loading conditions, and the NOX emission level is the highest under several loading conditions. Therefore, during the development of the national VI compliance of heavy-duty tractors, for the boundary condition of 10% loading, the focus is on more optimized thermal management, so that the SCR can be in a better operating temperature range and reduce the actual road. Risk of NOX emissions exceeding standards.

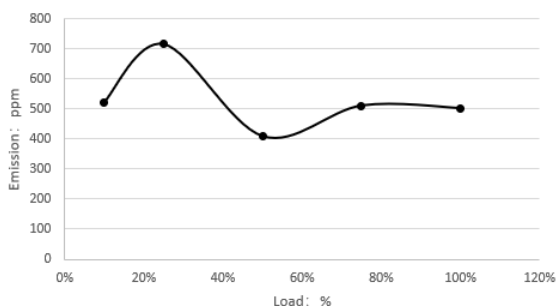


Fig. 8. CO emissions under different loads.

It can be seen from the above figure that under the conditions of PEMS cycle that meets the requirements of the national VI regulations, the car can meet the national VI b regulations under the load of 10%, 25%, 50%, 75%, and 100%. The requirements of the limits and can leave a lot of margin. CO emissions show a non-linear change with loading changes, with 25% CO emissions being the highest and 50% CO emissions being the lowest.

The CO emissions of the entire vehicle depend on the conversion efficiency of the engine's original exhaust and DOC in the aftertreatment. The optimal working temperature of DOC is 250 ° C ~ 350 ° C. After the engine water temperature reaches 70 ° C in the test, the internal measurement temperature of the DOC is within the optimal working temperature range. Under different loading conditions, the DOC conversion efficiency can reach more than 90%. The difference in CO emissions of the vehicle under different loadings is mainly reflected in the difference in the original row. Therefore, during the development of the national VI compliance of heavy tractors, the control of CO emissions must first optimize the in-cylinder emissions of the engine and install DOC at the vehicle level to verify.

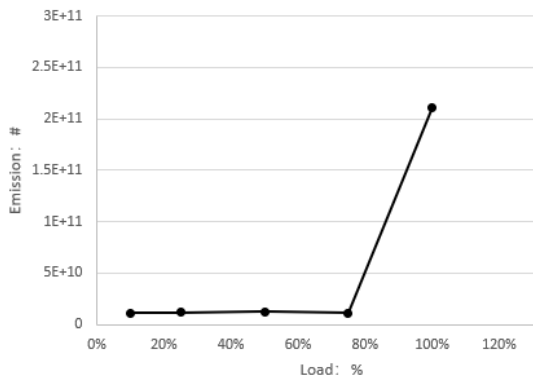


Fig. 9. PN emissions under different loads.

It can be seen from Figure 9 that under the conditions of the PEMS cycle that meets the requirements of the national six regulations, under the load of 10%, 25%, 50%, 75%, and 100%, the PN emission of particulate matter varies with the loading. The change of N is non-linear, and the amount of particulate matter PN is the largest when the load is 100%.

The amount of particulate matter PN mainly depends on the working conditions of the DPF module in the engine's original exhaust and aftertreatment equipment. Under normal circumstances, the DPF can filter out 95% of the particulate matter PN. The study found that the emission of particulate matter PN is inversely proportional to the exhaust flow of the engine. The exhaust flow is the largest under the condition that the vehicle is loaded with 100% load, so that the amount of particulate matter PN is also the highest under the condition of 100% load in emissions. As shown in the following table: During the development of the country's six heavy-duty tractors, the focus of the development of PN on the amount of particulate matter is to ensure the normal regeneration of DPF under the premise of reasonable selection, so as to maintain the actual filtration efficiency of DPF and the amount of particulate matter. The risk of PN is minimized.

Table 1. Average air flow rate of aftertreatment pipeline under different loads.

Load	Average exhaust flow rate
Load 10%	4.41
Load 25%	5.13
Load 50%	6.04
Load 75%	6.22
Load 100%	6.312

4 Conclusion

Based on the requirements of the actual road test regulations of the National Sixth Standard, a certain heavy-duty tractor has carried out PEMS cycle tests on actual roads at different loads of 10%, 10%, 25%, 50%, 75%, and 100%. The comparison test data shows that the operating conditions of the engine on the actual road are significantly different from the operating conditions of the WHTC cycle of the national six engine. For tractors at 10%, 25%, 50%, 75%, and 100%, respectively. The distribution characteristics of the engine operating conditions points required by the national road regulations under actual roads under load are compared and analyzed. The distribution of engine operating conditions points under different loads is different.

The comparative analysis of the emission conditions required by the State Road 6 regulations of the actual roads under 10%, 25%, 50%, 75%, and 100% loading of the tractor is performed. The reason for the highest emissions is the high-risk loading conditions during development. The optimization of NOX emissions during development focuses on the control of thermal management of the exhaust temperature at 10% loading; the correlation between CO emissions and loading conditions It is not very large, it mainly depends on the optimization of the original CO, and the normal ignition conditions of the post-processor DOC are met. During the development of National VI, the focus was on the maximum optimization of CO on the engine bench; the particulate matter amount PN emission was a high-risk loading condition under 100% loading. The compliance development for the particulate matter amount PN focused on the engine cylinder emissions Optimization, activation of DPF normal regeneration.

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