Technical research on the emission performance of vehicles with different Technique route under real driving conditions

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Abstract. Based on a large number of test data obtained from real driving emission test of gasoline vehicles, the emission performance of vehicles with different technique route under real driving conditions were studied, the emission sensitivities and feasible schemes to meet the China 6 RDE standards for vehicles with different technologies were also evaluated. It is revealed that for the tested fleet covering different emission control technologies and under current proposed RDE limit, the passing rate can reach 72% at the initial implementation stage of China 6 standard, and increased to more than 85% after more than one year of China 6 standard implementation, the main failure cause were the over standard emission of PN; the RDE pollution control level of domestic brands is equivalent to that of the foreign brands, but there is a certain gap between WLTC pollution control level; adding GPF is a relatively safe technology to deal with PN emission both in on road RDE tests and laboratory WLTC tests, and vehicles with additional coated GPF can obtain relatively better NOx emission performance.

1 Introduction

The number of on-road vehicles in China has been increasing year after year, and reached over 200 million science 2017. The increasing on-road vehicle has played a great positive role and far-reaching impact in optimizing the traffic structure, developing the economic output value, promoting social progress and so on. However, it is inevitable that the pollution emit by vehicles has become an important air pollution source in China, which can caused many environmental issues such as fine particulate matter, photochemical smog and so on. According to the preliminary calculation, the on-road vehicle emits over 43

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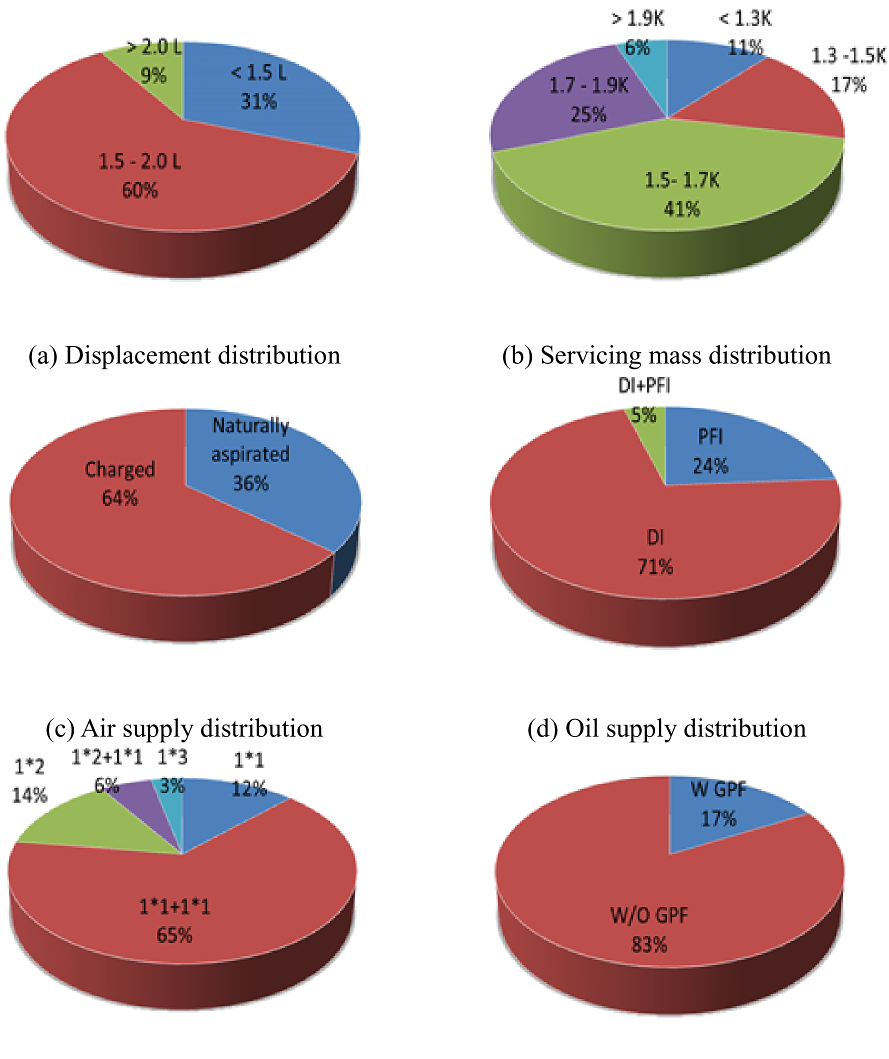
million tons of pollutants every year, of which the motor vehicle is the main contributor to the total pollutant emission, accounting for more than 80% of the total emission of CO and HC, and more than 90% of the total emission of NOx and PM [1].

In order to effectively control the emission of pollutants from motor vehicles, the state began to gradually implement emission standards for motor vehicles in the 1990s. Taking light-duty vehicle standards as an example, the first national standard was implemented in 1999, the second national standard was implemented nationwide in 2004, the third national standard was implemented nationwide in 2007, and the fourth national standard was implemented nationwide in 2014, The fifth national standard was implemented nationwide in 2017, and the latest sixth national standard had been published in December 2016, and was implemented nationwide in 2020 [2].

More and more stringent standards are conducive to promoting the progress of vehicle emission control technologies, taking the latest China 6 standard as an example, it considered more of the actual environmental emission control situations in China instead of simply following the European standards at the same stage as China 1 to China 5 standards. Instead, the China 6 standard flexibly learned from the experience of European and American standards, developed a new independent system by setting more stringent emission limits according to the actual situation of China, increasing more of the pollutant control types, adding new emission testing and regulatory requirements, all of which has brought unprecedented challenges and opportunities to China's automobile industry, especially for the upgrading of domestic brand emission control technologies. One of the biggest challenges in China 6 standard is the real driving emission test (RDE), which was first introduced by Euro 6 standard to reduce the deviation of pollutant emission between type approval laboratory test and actual pollutant emission from real in-use stage. The main reason of this deviation is that the type approvals are based on the fixed laboratory conditions which greatly underestimates the conditions and emission level of vehicles in real use. Taking NOx as an example, the maximum deviation can reach 710%. At the same time, there is a risk of subjective cheating in the emission test based on the laboratory. The most serious case was the "diesel gate" incident of Volkswagen in September 2015, which conducted emission cheating by identifying the vehicle certification status. After the "diesel gate", Volkswagen was punished by the United States and its market value evaporated at least $30 billion. In China, we are also facing the same problem, from China 1 to China 5 the deviation of pollutant emission between type approval and real in-use stage leaded to the in-use emission of vehicle products not accurately determined, which seriously affected the control effect of actual pollutants, restricts the formulation of national emission reduction policies and the accurate evaluation of the implementation effect of new standards, further affected the credibility of the government. Therefore, in China 6 standard, the RDE test requirement was added with portable on-board emission measurement system to evaluate the emission of vehicles on real road, which was hopefully to solve the huge emission deviations between type approval conditions and the real operating conditions that caused the vehicles emission "distortion" [3-12]. At the same time, considering that most cities in western China are located at an altitude over 1500 m, the China 6 RDE standard set a broader "extended" testing requirements from Euro 6’s 1300 m altitude requirement to 2400 m. The expanded boundary conditions put forward higher requirements for motor vehicle emission control and pollutant measurement technologies. In this study, through large samples of real driving emission tests, the performance of gasoline vehicles with different technique route under real conditions were studied, the emission sensitivities and feasible schemes to meet the China 6 RDE standards for vehicles with different technologies were evaluated.

2 Test and apparatus introduction

During the study, a test fleet covering different emission control technologies has been organized, with more than 80 vehicles had been tested. The vehicles with different technique route are classified as in Figure 1, covering 1.0-3.0 liter displacement, 1000-2200kg curb weight, among which, the 1.5-2.0 L vehicles which are commonly seen in China market accounts for about 60%, and the servicing mass of 1.5-1.7 ton accounts for 41%. The air intake modes include naturally aspirated and turbocharged, which account for about 36% and 64%, respectively. For different fuel supply modes, the direct injection accounts for 71%, the multi-point port fuel injection accounts for 24%, and the mixed injection accounts for 5%. Among the test fleet 65% vehicle chose 1*1+1*1 as the distribution of catalytic unit and 83% chose not to use GPF.



(a) Displacement distribution (b) Servicing mass distribution

(c) Air supply distribution (d) Oil supply distribution

(e) Catalytic unit distribution (f) GPF distribution

Fig. 1. Test fleet classification as different technique routes.

The RDE test conditions include urban condition (< 60 km / h), rural condition (60-90 km / h) and motor-way condition (> 90 km / h) differentiated by vehicle speed. The driving mileage of each working condition shall not be less than 16 km, and the mileage proportion shall be 34%, 33% and 33% respectively, with allowable drift of ±10% for each proportion, but the proportion of urban should not be less than 29%. The typical test conditions are shown in Figure 2.

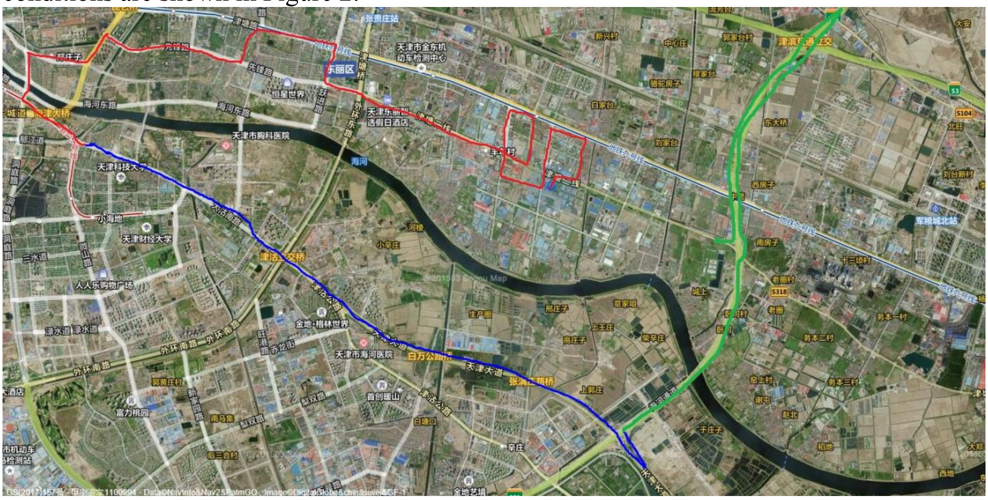


Fig. 2. The typical RDE test conditions, (the red line, blue line and the green line represent the urban, rural and motor-way conditions respectively).

The total length of the test condition is about 65 km, including 20 km of urban condition, 21 km of rural condition and 23 km of motorway condition. The driving section includes typical urban conditions, such as schools, hospitals, shopping malls and other densely populated and one-way sections with a speed limit of 30 km / h, while a expressway with a speed limit of 80 km / h is selected to constitute the rural conditions, and the motorway condition is carried out in a normal highway road with a speed limit of 120 km / h. The typical test conditions are shown in Table 1.

Table 1. The typical RDE test conditions.

	urban	rural	motorway	total	unit
Distance	20.5	21.3	23.4	65.2	km
Duration	60	17	13	90	min

Portable emission measure systems (PEMS) were used as the test apparatus, which is an integrated vehicle exhaust gas analysis system with integrates high-precision emission analyzer, flow meter and main control computer. The PEMS can measure and record the volume concentration, particle number (PN) and exhaust flow of NOx, CO, CO2 and other components in vehicle exhaust in real time. Through the GPS module, weather station module and OBD interface, the geographic information, environmental parameters, operating parameters and other essential basic parameters for analyzing and testing the vehicle emission rate and vehicle emission level, such as torque, speed, longitude and latitude, altitude, temperature, humidity and driving speed can also be obtained. In this study, a portable AVL M.O.V. E system was used for the RDE measurement, the appearance of M.O.V.E is shown in Figure 3 and the technical specifications are listed in Table 2. Generally, the 22 ~ 28.8 V DC power supply is used, the concentration of CO and

CO_2 is measured by Non-Dispersive Infra-Red (NDIR), the concentration of NOx is measured by Non-Dispersive Ultra-Violet spectroscopy (NDUV), and the concentration of PN is measured by diffusion charger (DC).

Fig. 3. The AVL M.O.V. E apparatus.

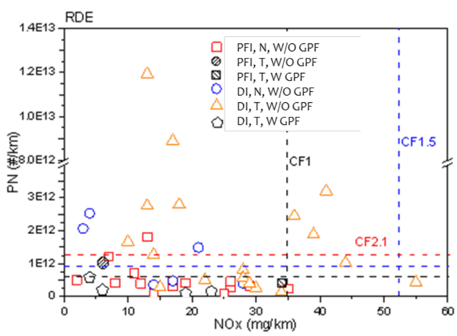
Table 2. The technical specifications of AVL M.O.V. E.

Emission	Measuring principle	Measuring range	Accuracy
CO	NDIR	(0-15) vol%	1ppm
CO2	NDIR	(0-20) vol%	0.01vol%
NO	NDUV	(0-5000) ppm	0.1ppm
NO2	NDUV	(0-2500) ppm	0.1ppm

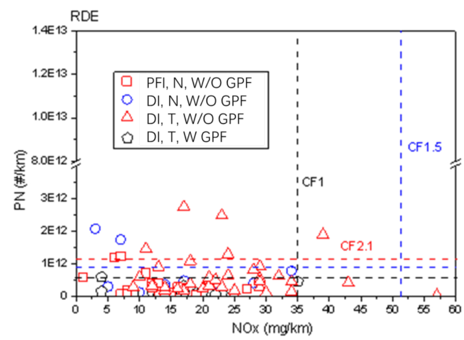
3 Results and analysis

The emission results of the test fleet are shown in Figure 4, where Figure (a) and (b) represents the emission levels of new vehicle models at the initial implementation stage and more than one year after the implementation stage of the China 6 standard, respectively. It can be seen from Figure 4 (a) that in the early stage of China 6, the main vehicle manufacturers were still reserving technical routes to cope with the new standard, expressing as various possible technical routes choice in the market, including different options in air supply systems, oil supply systems, charge systems, after-treatment systems, and so on. The common technical routes can be divided into 6 classes at that time as: natural aspirated port fuel injection vehicle without GPF (simplified as PFI, N, W/O GPF in Figure 4), turbocharged port fuel injection vehicle without GPF (simplified as PFI, T, W/O GPF) , turbocharged port fuel injection vehicle with GPF (simplified as PFI, T, W GPF), natural aspirated direct injection vehicle without GPF (simplified as DI, N, W/O GPF), turbocharged direct injection vehicle without GPF (simplified as DI, T, W/O GPF) , and turbocharged direct injection vehicle with GPF (simplified as DI, T, W GPF). It can be revealed from Figure 4 (a) that the new vehicle models at the initial China 6 implementation stage were quite good while facing the newly added RDE requirements, the passing rate of the fleet can reach 72% under the current proposed RDE limits, which are now 2.1 times of the China 6 type I limits (known as CF = 2.1). It is also revealed in Figure 4 (a) that the main failure cause were the over standard emission of PN, which were more prominent in vehicles without GPF, especially for direct injection types. Considering that the China 6 RDE regulations are likely to follow the European standard which had already tightened the CF requirements from 2.1 to 1.5 and will be set to 1 in 2023. In the worst CF = 1.0 case, more than 43% of the models would fail in RDE test, but on the other hand, the models with GPF can still guarantee 100% of the RDE pass rate. Considering to meet the increasingly stringent fuel consumption requirements, enterprises will gradually increase the development of direct injection vehicles. In this case, GPF is a relatively safe technology to deal with RDE regulations.

It is also revealed in Figure 4 (b) that after more than one year of China 6 standard implementation, the technical routes selections of the main vehicle manufacturers were more concise, and the common choice simplified into 4 classes: natural aspirated port fuel injection vehicle without GPF, natural aspirated direct injection vehicle without GPF , turbocharged direct injection vehicle without GPF, and turbocharged direct injection vehicle with GPF. And we can see from Figure 4 (b) that after more than one year of development, the pollution control technology of the whole industry has become more mature, the RDE performance were still good even though most of the models were not equipped with GPF. The exceeding rate of RDE can be controlled within 15% even with 1.0 of CF after matching with in-cylinder purification and effective after-treatment.



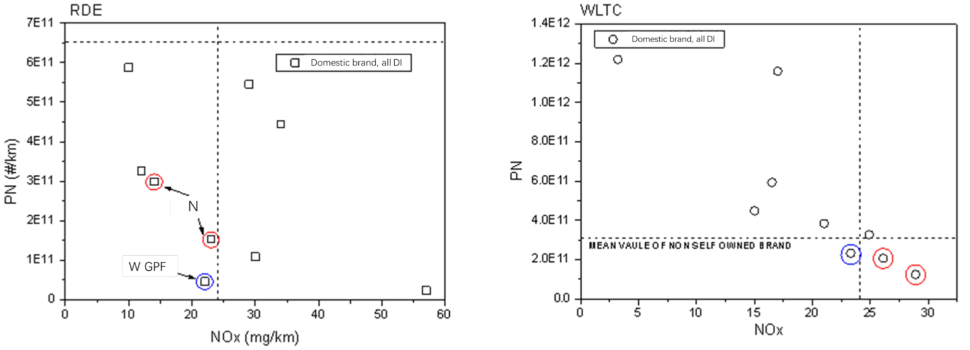
a) vehicle models at the initial implementation stage of China 6 standard



b) vehicle models after more than one year of China 6 standard implementation

Fig. 4. The RDE emission levels of new vehicle models.

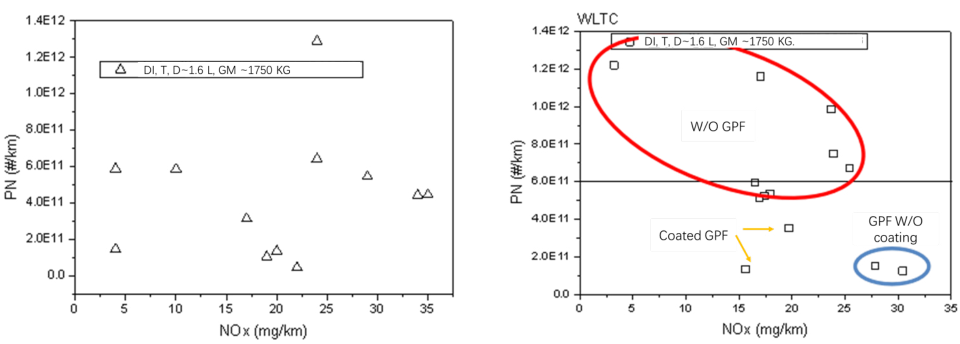
In addition, in the initial implementation stage of China 6 standard, there were few domestic brands in the fleet, and after more than one year of China 6 standard implementation, more and more domestic brands had emerged in the market. The technical routes adopted by domestic brands are commonly natural aspirated direct injection vehicle without GPF , turbocharged direct injection vehicle without GPF , and turbocharged direct injection vehicle with GPF, and most of them adopted multi-stage catalysis. Their emission levels were shown in Figure 5, where (a) and (b) show the emissions during on road RDE tests and laboratory WLTC tests respectively. The black dotted line shows the average pollutant emission of the bench-marking foreign brands. It can be seen from Figure 6 that the RDE pollution control level of domestic brands is equivalent to that of the foreign brands, but there is a certain gap between WLTC pollution control level. In general, Figure 5 shows that the technical reserve of the domestic brand has great potential to meet the China 6 emission requirements.



(a) the RDE emission level of domestic brands (b) the WLTC emission level of domestic brands

Fig. 5. The emission levels of domestic brands during on road RDE tests and laboratory WLTC tests.

Take the common 1.6L displacement turbocharged direct injection vehicle on the market as an example, the emission levels of the target models during on road RDE tests and laboratory WLTC tests are shown in Figure 6, it can be revealed in Figure 6 that the targeted domestic models with GPF can achieve good PN emission reduction effect, but due to the cost or technical constraints, most of the domestic brand vehicles adopt the relatively conservative strategy without GPF, but this brings risk of exceeding the $6x10^{11}$ / km PN standard during WLTC tests. And it can be foresee that unless more advanced in-cylinder purification and after-treatment calibration technologies are introduced, the trend of adding GPF to limit PN emission is the technical route that can not be bypassed. It can also be revealed in Figure 6 that the domestic brand vehicles had little problem in NOx control, but several vehicles with un-coated GPF had relatively higher NOx emissions that were very close to the NOx emission limit of China 6 standard, while vehicles with additional coated GPF can obtain relatively better NOx emission reduction effects.



(a) the RDE emission level of target models (b) the WLTC emission level of target models

Fig. 6. The emission levels of the target domestic models during on road RDE tests and laboratory WLTC tests.

4 Conclusions

Based on a large number of test data obtained from real driving emission test of gasoline vehicles, the emission performance of vehicles with different technique route under real driving conditions were studied, and the following conclusions are obtained:

1) For the tested fleet covering different emission control technologies and under current proposed RDE limit, the passing rate can reach 72% at the initial implementation stage of China 6 standard, and increased to more than 85% after more than one year of

China 6 standard implementation, the main failure cause were the over standard emission of PN;

2) The RDE pollution control level of domestic brands is equivalent to that of the foreign brands, but there is a certain gap between WLTC pollution control level;

3) GPF is a relatively safe technology to deal with PN emission both in on road RDE tests and laboratory WLTC tests, while vehicles with additional coated GPF can obtain relatively better NOx emission performance.

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Abbreviations

RDE	–	Real driving emissions
GPF	–	Gasoline Particulate Filter
ISC	–	In-Service Conformity
PFI	–	Port fuel injection
DI	–	Direct injection
PEMS	–	Portable Emissions Measurement Systems
LDV	–	Light-duty vehicle

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