Driving Characteristics Analysis of Light-duty Vehicle RDE Test in Plain and Plateau

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Abstract. In this paper, 8 real-driving emission (RDE) tests were conducted by using a portable emission measurement system (PEMs), and the intensity value was defined to quantitatively express the driving intensity of vehicles. Four plains RDE experiment and four plateau RDE driving characteristics were analysed. At the same time, the transient characteristics of plain test 3 and plateau test 2 with close and stable driving intensity and plain test 1 with high driving intensity were compared. Results show that compared with the plain RDE test, driving intensity of plateau RDE test overall is low, and the frequent acceleration and deceleration times of the plateau RDE test in the urban section are few, besides the acceleration is relatively large. The intensity of driving can have a big impact on pollutant emissions, especially in highway section. The acceleration of the plateau RDE test in the urban section is large, and the CO emission is high due to the climatic conditions and road conditions. Therefore, the frequent acceleration process of the plateau test in the urban section should be paid special attention to when the vehicle is conducting calibration test. In conclusion, from a test method point of view, the driving intensity of the RDE test should be required; From the point of view of calibration development, we should focus on the condition of high driving intensity.

1. Introduction

The continuous development of automobile industry has brought great crisis and challenge to the global environment. In order to deal with more and more serious environmental problems, countries around the world adopt more stringent regulations to control and supervise vehicle emissions. Laboratory test method is the main measure of vehicle emission management at present, but it can only measure the vehicle emission level under some specific conditions. In real road driving process, the driving conditions of vehicles vary greatly. Combined with the differences in environmental conditions, the emissions of vehicles are extremely different. Research shows that the real road driving emissions of vehicles are much higher than the emission values measured in the laboratory [1-3].

In order to solve the above problems, the emission regulations of China's light-duty vehicle emission limits and measurement methods (China's sixth stage) issued in December 2016 refer to the European Union's emission regulations (the sixth stage), and change type I test cycle from new European driving cycle (NEDC) to word light duty test cycle (WLTC), and at the same time change the real driving emission (RDE) test is introduced as a type II test to supplement the laboratory test[4].

RDE test can cover a wide range of driving and environmental conditions, so it can better reflect the real driving emissions. However, the test results show that the RDE test results are greatly affected
by environmental conditions and driving behaviour, which results in the great difference between the RDE test results. In this paper, the author makes a comparative analysis of 8 RDE test results in plain and plateau of driving characteristics [5-6].

2. Test equipment and scheme

2.1. Test equipment

The gas analyser of PEMS used in this paper can measure CO, NOₓ and HC, and the particle measurement equipment can measure particle quality and particle quantity of the exhaust. GPS can record the geographical position, altitude and speed of the vehicle in second by second. Weather stations can record the ambient temperature and relative humidity. PEMS can also record relevant data in the vehicle ECU. Before the test, the equipment should be checked for leakage, zeroing and calibration, and then drift checked after the test.

In this paper, a China's sixth stage vehicle is selected for RDE test. The vehicle is a small SUV with a turbocharged direct injection engine with a displacement of 1.0L. See Table 1 for specific vehicle parameters.

| Content                        | Parameter       |
|--------------------------------|-----------------|
| Vehicle grade                  | SUV             |
| Curb weight                    | 1309kg          |
| Gearbox type                   | DCT             |
| Environmental protection standard | China VI       |
| Engine displacement            | 1.0L            |
| Intake form                    | Turbo charger   |
| Fuel supply mode               | GDI             |
| Maximum power                  | 93kW            |
| Maximum torque                 | 194N•m          |
| Rated speed                    | 5500rpm         |

2.2. Test route

In order to meet the requirements of national six emission laws and regulations, RDE test routes were selected in Tianjin and Xining for actual road emission test. The average total distance of the four RDE tests in Tianjin is 71.6km. The proportion of urban, rural and highway trips is 30.6%, 31.5% and 37.9% respectively, and the total test time is 98.8min. The average total distance of four RDE tests in Xining is 80.6km. The proportion of urban, rural and highway trips is 33.3%, 30.8% and 35.9% respectively. The total test time is 99.7min. All the 8 tests meet the requirements of China's sixth stage regulation.

2.3. Test scheme

The test process followed the requirements of China's sixth stage regulations. Firstly, WLTC was carried out to determine the CO₂ emission characteristic curve of the vehicle, then the PEMS equipment was preheated and the measurement results were calibrated to ensure that the PEMS equipment status is normal, and then the real driving emission test was carried out.

In this paper, four RDE tests were carried out on the plain and plateau of the same six small SUV models of a certain manufacturer. Tianjin was chosen as the RDE test city of plain, and Xining, Qinghai Province, was chosen for plateau RDE test. Vehicle parameters and test conditions are shown in Table 1 and table 2. The average altitude of the four plain RDE tests is about 4.3m, the average
temperature is about 33.5°C, and the relative humidity is about 49.2%. The average altitude of the four plateau RDE tests is about 2300m, the average temperature is lower than that of the plain, about 5°C, and the relative humidity is roughly the same as that of the plain.

Table 2. Test conditions

| Num. | Location | Mean altitude (m) | Average temperature (degC) | Relative humidity (%) |
|------|----------|------------------|-----------------------------|-----------------------|
| 1    | Tianjin  | 2.9              | 30.2                        | 57.0                  |
| 2    | Tianjin  | 5.9              | 35.4                        | 39.9                  |
| 3    | Tianjin  | 3.9              | 34.6                        | 49.5                  |
| 4    | Tianjin  | 4.3              | 33.8                        | 50.2                  |
| 5    | Xining   | 2309.2           | 5.6                         | 57.7                  |
| 6    | Xining   | 2312.7           | 4.6                         | 29.7                  |
| 7    | Xining   | 2308.2           | 6.2                         | 39.0                  |
| 8    | Xining   | 2311.5           | 5.2                         | 45.5                  |

3. Analysis of test results

3.1. Calculation of driving dynamics parameters

In order to avoid the excessive or insufficient dynamic characteristics in the driving process of urban, rural, and highway section, China VI regulations request to check \( v \cdot a_{\text{pos}} \) [95] and RPA which are two representative kinetic parameters. \( v \cdot a_{\text{pos}} \) [95] is the 95% fractional corresponding value of the product of vehicle speed and positive acceleration (\( > 0.1 \text{m/s}^2 \)). The calculation formula of relative positive acceleration (RPA) is as follows:

\[
RPA_k = \frac{\sum_j (\Delta t \cdot (v \cdot a_{\text{pos}})_{j,k})}{\sum_i d_{i,k}}
\]  

(1)

China VI regulations require that if \( \overline{v_k} \leq 94.05 \text{km/h} \) and \( RPA_k < (-0.0016 \cdot \overline{v_k} + 0.1755) \), the trip is invalid; If \( \overline{v_k} > 94.05 \text{km/h} \) and \( RPA_k < 0.025 \), the trip is invalid.

In this paper, the difference between the actual value and the check value of RPA in the regulations is defined as driving intensity. The greater the driving intensity value, the RPA value of the travel far exceeds the check value in the regulations, and the more intense the driving. If the driving intensity is negative, the trip is invalid.

\[
RPA_{\text{intensity},k} = RPA_k - RPA_{\text{check},k}
\]  

(2)

\[
RPA_{\text{check},k} = \begin{cases} 
-0.0016 \cdot \overline{v_k} + 0.1755, & \overline{v_k} \leq 94.05 \text{km/h} \\
0.025, & \overline{v_k} > 94.05 \text{km/h} 
\end{cases}
\]  

(3)

The above calculate method was used to analyse the intensity of the 8 RDE test results. The data in red in Table 3 represent the driving intensity, while green represents the driving stability. It can be seen that test 1 and test 2 were the most intense and the 4 plateau RDE tests were relatively stable.

Table 3. Intensity of RDE tests

| Num. | Results | urban | rural | highway |
|------|---------|-------|-------|---------|
| 1    | Check value | 0.1203 | 0.0543 | 0.0250  |
|      | Intensity value | 0.0468 | 0.1320 | 0.1292  |
| 2    | Check value | 0.1185 | 0.0544 | 0.0250  |
|      | Intensity value | 0.0464 | 0.1301 | 0.1584  |
| 3    | Check value | 0.1753 | 0.1752 | 0.1752  |
|      | Intensity value | 0.0257 | 0.0308 | 0.0454  |
Figure 1 shows the average speed of urban, rural and highway sections of the plain and plateau RDE test. The 8 RDE tests all met the requirements of China 6 regulations. It can be seen that the average speed of rural and highway sections in plain and plateau tests is basically the same, while the average speed of urban sections in tests 1, 2 and 7 is slightly higher.

The datasets with acceleration greater than 0.1 m/s$^2$ in urban, rural and highway sections of the plain and plateau RDE test were shown in Figure 2. According to the requirements of China 6 regulations, the data volume of each velocity group whose acceleration is greater than 0.1 m/s$^2$ should not be less than 150, which is obviously satisfied by 8 RDE tests. By comparing the results of the plain test and the plateau test, it can be seen that the data amount of positive acceleration in the urban section of the plateau test is significantly lower than that in the plain test, while the data amount of positive acceleration in the rural and highway sections is basically the same as that in the plain test.

According to China VI regulations, the $v_{a_{pos}}[95]$ of each speed group is required not to exceed the check value. In this paper, both the plain and plateau RDE tests meet the conditions and the trip is valid. As can be seen from Figure 3, in the urban section, $v_{a_{pos}}[95]$ of the 4 tests on the plateau was larger than $v_{a_{pos}}[95]$ of the plain test on the whole, while $v_{a_{pos}}[95]$ of the 1 and 2 rural and highway sections was the largest, while $v_{a_{pos}}[95]$ of the 3 and 4 rural and highway sections was the smallest.

Figure 4 shows the relative positive acceleration of each velocity group in the plain and plateau tests. Compared with the four tests in the plain, the RPA in the highway section of the four tests in the plateau was lower.
3.2. Transient feature

In order to analyse the influence of driving characteristics and environment on emissions, plain test 3 and plateau test 2 with close and stable driving intensity were selected, and plain test 1 with high driving intensity was selected for comparative analysis.

Figure 5 shows the distribution point of velocity and acceleration for the three tests. It can be seen that the acceleration distribution range of the plateau test is wider. In urban section, the acceleration of plateau test was greater.

Figure 6 shows the transient results of three tests, including instantaneous speed, acceleration, CO emission, NOx emission and PN emission. In the three tests, the emissions of all three pollutants were large during the vehicle start-up stage. The emission result of highway section of test 1 was the worst; in the highway segment of test 3, there was a peak of the emission of the three pollutants, which occurred when the speed of the highway segment increased rapidly, and the other two peaks of PN emission occurred when the speed of the rural segment accelerated rapidly. In test 7, the CO emission value of urban section and highway section appeared several peaks, but NOx and PN emissions were small.
Figure 6. Transient results of three RDE tests
By comparing the results of plain test 3 and plain test 1 in Figure 6 (a) and Figure 6 (b), it can be concluded that the pollutant emission is larger under the condition of high vehicle speed and large acceleration. In other words, aggressive driving can lead to bad results in vehicle emissions. This is because if the vehicle wants to reach a large speed in a short time, it is bound to increase fuel injection for thickening, resulting in a large amount of CO and PN generated by incomplete combustion. At the same time, the deviation of the air-fuel ratio from stoichiometric ratio will also lead to the reduction of the conversion efficiency of the ternary catalytic converter and the increase of the emissions of the three pollutants.

Similarly, the comparison between plain test 3 and plateau test 7 with similar driving intensity shows that the CO emission of plateau test is higher than that of plain test. This is due to the low atmospheric pressure in the plateau test, small air intake, and in the process of vehicle acceleration, the amount of oil injection increases, making CO combustion insufficient. But the PN emissions from plateau 7 were no higher than those from plain 3. This may be because this car is equipped with GPF, which has a better particle capture effect. Due to the low ambient temperature in the plateau test and the low inlet temperature, the oxygen content in the air is low, which is not conducive to the formation of NOx.

4. Conclusion

In this paper, driving intensity was defined, and driving characteristics of 4 plain RDE tests and 4 plateau RDE tests were analyzed. At the same time, the transient characteristics of plain test 3 and plateau test 2 with close and stable driving intensity and plain test 1 with high driving intensity were compared. The conclusions are as follows:

1) Compared with the plain RDE test, the driving intensity of the plateau RDE test was lower on the whole, and the frequent acceleration and deceleration times of the plateau RDE test in the urban section were less, but the acceleration was relatively larger.

2) The intensity of driving has a great impact on the emission of pollutants, especially in highway section when the vehicle is accelerating rapidly.

3) The acceleration of the plateau RDE test in the urban section is large, and the CO emission is high. Therefore, the frequent acceleration process of the urban section of the plateau test should be paid special attention to during the calibration test.

4) From a test method point of view, the driving intensity of the RDE test should be required; From the point of view of calibration development, we should focus on the condition of high driving intensity.

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