Tracing method of remote sensing exhaust analysis device

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Abstract. Vehicle exhaust emissions are one of the main sources of air pollution. The remote sensing measurement system for vehicle emission pollutant can carry out real-time monitoring on vehicles running on the road, and screen high-emission vehicles, which has a significant effect on the regulation and control of vehicle exhaust. The scientific traceability of remote sensing exhaust analysis device can ensure the accuracy of the test data, thus ensuring the accurate screening of high-emission vehicles. This paper studies the traceability method of remote sensing exhaust analysis device, and develops the corresponding calibration device. It can realize the accurate traceability of remote sensing exhaust analysis device, and play a positive role in the application of this device and the control of vehicle exhaust.

1. Introduction

With the growing number of vehicles in the world, the pollution of vehicles exhaust to the atmospheric environment is becoming increasingly serious, and exhaust emission pollution has become an urgent problem [1-3]. At present, the main methods used to detect the exhaust gas of vehicles are simple working condition method, loading deceleration working condition method, tunnel test, remote sensing test, vehicle-mounted test, etc [4-6]. The remote sensing measurement system for vehicle emission pollutant is one of the efficient technical means to detect whether the vehicle has high emissions. It has the advantages of not affecting the normal driving of the vehicle, fast detection speed and high degree of automation.

The remote sensing measurement system for vehicle emission pollutant is a large comprehensive system, generally including remote sensing exhaust analysis device, speed measurement device, meteorological parameter analysis device, road slope measurement device, vehicle license recognition system and control management computer system, etc. The remote sensing exhaust analysis device is the most important part for detect the high emission vehicle, which shows the gas concentration of real-time monitoring.

Since this device is used in environmental monitoring and law enforcement, the accuracy of its test data and measurement value traceability are particularly important, especially the remote sensing exhaust analysis device. Therefore, it is urgent to investigate the traceability method of the remote sensing exhaust analysis device, and it will provide a strong support for the popularization and application of measurement system for vehicle emission pollutant, thus making a positive contribution to the control of air pollution and the improvement of air quality.
2. Measurement setup

The principle of remote sensing detector is based on Lambert-Beer law [7], which can be expressed as follows:

\[ T = \frac{I(\lambda)}{I_0(\lambda)} = \exp(\beta c L) \]  

Which the \( T \) is the transmittance after transmission distance \( L \), \( L \) is the distance at which the light beam through exhaust mass, \( c \) is the percentage gas concentration by volume, and \( \beta \) is the gas absorption coefficient.

Since the remote sensing exhaust analysis device is an open measurement in the actual road, the \( L \) value in the optical path cannot be determined. In addition, when standard gas entering into the atmosphere, it will be diluted to some degree. Thus, it is difficult to retain the original characteristics of standard gas, and the concentration of exhaust cluster does not represent the concentration of standard gas. Therefore, it is difficult to trace the source of gas analysis device.

Although the absolute concentration of exhaust gas changes rapidly in the atmosphere, the relative ratio of various gas remains almost unchanged in a short time (<1 s). The gas analysis device directly measures the ratio of \( \text{CO, HC, NO}_x \) and other gas to \( \text{CO}_2 \) in the smoke mass. According to the combustion theory, the ratio of \( \text{CO, HC, NO}_x \) to \( \text{CO}_2 \) can be used as the criterion for whether the fuel combustion is sufficient or not. According to the combustion equation and the measured ratio, the concentration of each gas in the vehicle exhaust can obtain. Therefore, the calibration device should be able to generate a fixed length air mass, which the light beam of remote sensing exhaust analysis device can pass through the smoke mass in a short time, and measure the concentration of the gas.

The schematic diagram of remote sensing exhaust analysis device and calibration device placement is shown in Figure 1. The schematic diagram and photos of the calibration device are shown in Figure 2, the device is composed of light channel, gas chamber, exhaust fan, gas inlet and other parts. The gas chamber of the device can open instantaneously, allowing the test light beam to pass through. During the calibration, the calibration device place in the middle of the light channel of the remote sensing exhaust analysis device. When the cover body of the gas chamber is closed, it has two functions. One is to block out the light beam to simulate a car passing by, and another is to allow the standard gas entering into the gastight chamber. When the oxygen sensor at the outlet detects the oxygen content is less than 0.1%, it indicates the standard gas in the gas chamber has replaced all the air. Then, the cover body of gas chamber open, which simulates the state of vehicle exhaust, and the standard gas in the chamber is measured by the remote sensing exhaust analysis device. The calibration device takes full advantage of the fast measurement speed of remote sensing equipment, which completes all the detection work within 0.7 s. The standard gas mass used for calibration can form in the instant, while can satisfy the characteristics of open measurement.
After the “start” operation in the main control panel, the internal solenoid valve, electromagnetic relay, oxygen sensor and other components can be controlled. The whole process, including the entry of the standard gas, the opening and closing of the cover body, and the monitoring of the oxygen sensor can be carried out automatically according to the set workflow, which is characterized by high degree of automation, strong stability and high efficiency.

The working flow chart of calibration device is shown in Figure 3. After the calibration work starts, the calibration device is placed in the middle of the light path of the remote sensing exhaust analysis device. The position of the calibration device is adjusted according to the laser aligner beside the light path, so that the light path can pass through the gas chamber quickly. Click the “start” button on the control panel of the calibration device, the cover body at both ends of the calibration chamber will close, which simulates the passing vehicle. At this time, the standard gas fill into the gas chamber, and oxygen sensor start monitoring the oxygen content in the chamber. When the oxygen content is less than 0.1%, showing the gas chamber filled by the standard gas and the air is emptying. The cover body of the gas chamber is opened at this time, and the light beam of remote sensing exhaust analysis device pass through the gas chamber to measuring. After recording the test data, standard gas in the chamber will be vented by the exhaust fan. The calibration work finished after the above steps completed.

### 3. Results and discussion

In order to verify the accuracy and reliability of the measurement results of the calibration device and determine the relevant parameters and technical indicators of the device, the calibration test carried out and the results were analyzed. We choose four kinds of standard gas to measure. The error test and repeatability results are shown in Table 1 and Table 2, respectively. All the results show a good error and repeatability, indicating the calibration device is available. And it also provides data reference and support for the formulation of relevant standards and specifications.
Table 1. Error test results

| concentration of standard gas | 1   | 2   | 3   | average value | indicator value | absolute error | relative error |
|------------------------------|-----|-----|-----|---------------|-----------------|----------------|----------------|
| HC ($\times 10^{-6}$)        | 1150| 1137| 1142| 1169          | 1149            | -0.67          | -0.06%         |
| CO ($\times 10^{-2}$)        | 3.31| 3.24| 3.23| 3.38          | 3.28            | -0.03          | -0.81%         |
| CO$_2$ ($\times 10^{-2}$)    | 12.71| 12.47| 13.27| 12.50        | 12.75          | 0.04           | 0.29%          |
| NO ($\times 10^{-6}$)        | 998 | 941 | 958 | 1010         | 970            | -28.33         | -2.84%         |

Table 2. Repeatability test results

| standard gas | test results | average value | relative Standard deviation |
|--------------|--------------|---------------|-----------------------------|
| HC ($\times 10^{-6}$) | 503 | 496 | 501 | 480 | 499 | 492 | 1.27% |
| CO ($\times 10^{-2}$) | 0.490 | 0.486 | 0.499 | 0.510 | 0.503 | 0.5 | 0.498 | 0.00% |
| CO$_2$ ($\times 10^{-2}$) | 14.57 | 13.89 | 14.67 | 15.02 | 15.09 | 13.99 | 14.54 | 0.10% |
| NO ($\times 10^{-6}$) | 2980 | 3009 | 2988 | 3039 | 2999 | 2966 | 2997 | 3.61% |

4. Conclusion
This paper studies the traceability method of remote sensing exhaust analysis device, and the calibration device can realize the calibration of the device. The calibration device is composed of light channel, gas chamber, exhaust fan, gas inlet and other parts. The whole calibration work can be completed in a short time, which facilitates the efficiency and application of the remote sensing exhaust analysis device. The test results show a good error and repeatability, indicating the calibration device is available and providing data reference and support for the formulation of relevant standards and specifications.

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