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Calibration specification for remote sensing measurement systems of vehicle exhaust

机动车尾气遥感检测系统校准规范

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Calibration specification for remote sensing measurement systems of vehicle exhaust

1 Scope

This specification applies to the calibration of the remote sensing measurement system for motor vehicle exhaust.

2 Reference documents

This specification refers to the following documents:

HJ 845 Measurement methods and technical requirements for exhaust pollutants from diesel vehicles in use (remote sensing method)

JB/T 11996 General technical requirements of remote sensing equipment for motor vehicle exhaust

For dated reference documents, only the dated version applies to this specification; for undated reference documents, the latest version (including all amendments) applies to this specification.

3 Terms

3.1 Remote sensing method

A method of remote sensing and measuring the exhaust gas concentration of a driving motor vehicle using optical principles.

[Source: HJ 845-2017, 3.2, with modification]

3.2 Vehicle exhaust

The gaseous pollutants and particulate matter emitted from the exhaust pipe of a motor vehicle, which refer to CO, CO_2, HC, NO and particulate matter in this specification.

3.3 Opacity

The flux absorption percentage of the light emitted from the light source passes through the exhaust plume of the motor vehicle and reaches the light receiver of the instrument, which is generally represented by the symbol N.

[Source: HJ 845-2017, 3.8, with modification]

3.4 Standard reducing light dimmer

A standard device that uses a physical method to block light from passing through in accordance with a prescribed ratio, which is the opacity of the standard reducing light dimmer.

3.5 Background value

The state of ambient gas before remote sensing of motor vehicle exhaust gas, which refers to the environmental background value.

4 Overview

Remote sensing system for motor vehicle exhaust (hereinafter referred to as remote sensing system) is a measurement system that uses remote sensing to detect the exhaust of motor vehicles traveling within a specified speed range under certain weather conditions and road slopes. It can measure the exhaust gas value of motor vehicles on the road without affecting the normal driving of motor vehicles. Its working principle is: the mainframe of the remote sensing system emits a light beam; when a motor vehicle passes, the exhaust gas interferes with the light beam; the spectrum, intensity and other characteristics of the light received by the receiving end will change; this change can reflect the concentration of the measured exhaust gas or changes in opacity. At present, the light sources used in the remote sensing system are laser, infrared heat radiation, ultraviolet light, yellow-green light.

The remote sensing system is mainly composed of exhaust gas measurement devices (generally including gas measurement devices and opacity measurement devices for measuring particulate pollutants, or only one of them), speed measurement devices, road slope measurement devices, meteorological parameter measurement devices, vehicle number plates identification system, control and management computer system, etc. Its usage is divided into the following three types: horizontal mobile remote sensing system, horizontal fixed remote sensing system, vertical fixed remote sensing system.

5 Metrological characteristics

5.1 Exhaust gas measuring device

5.1.1 Gas measuring device

$\overline{C}$ - The arithmetic average of n measurements.

$$s_a = \frac{s_A}{\overline{C}} \times 100\% \quad (4)$$

Where:

s_a - Relative standard deviation.

7.1.3 Dynamic calibration of indication error of gas measuring device

7.1.3.1 Turn on the power supply and perform warm-up according to the time specified in the gas measurement device manual. After the warmup is completed, adjust the light path of the gas measurement device, to make the gas measurement device meet the working requirements specified in the manufacturer's manual.

7.1.3.2 After all preparations for the gas measuring device are completed and the light path of the emission pollutant gas measuring device is not affected, the gas calibration auxiliary device is placed in the detection light path to make it meet the working requirements specified in the manufacturer's instructions. The connection of the gas calibration auxiliary device is as shown in Figure 1.

7.1.3.3 When ready, read the background value of the gas measuring device. Select the standard gas No.2 and No.3 as specified in Table A.1 or Table A.2. If the standard gas in Table A.2 is used for testing, the corresponding standard gas in Table A.1 must also be selected. Adjust the flow rate of the dynamic gas calibration device to 20 L/min according to the requirements; the injection time is about 0.5 s. Inject the standard gas into the dynamic gas calibration device according to the predetermined procedure. Record the gas mole fraction indication of the gas measuring device. Follow the above steps, to repeat the measurement 3 times for each mole fraction gas.

7.1.3.4 Calculate the indication error according to formula (1) and formula (2).

7.2 Opacity measuring device

7.2.1 Calibration of indication error

Turn on the power. The operator will warm up according to the time specified in the opacity measuring device manual. After the preheating is completed, adjust the optical path of the opacity measuring device, to make the opacity measuring device reach the requested work state as specified in the manufacturer's manual.

$$\delta_v = \frac{\Delta v}{v_0} \times 100\% \tag{8}$$

Where:

δ_v - Relative error of the speed measuring device.

7.3.1.2 Acceleration indication error

a) Install and adjust the standard speedometer according to the use requirements to make it in normal working condition. Select any three accelerations within the range of (-1 ~ 2) m/s^2 as calibration points, but there must be a calibration point less than 0 m/s^2. The acceleration calibration points can also be determined according to the actual conditions of the measured road.

b) According to the calibrated acceleration point, the limit value of the speed measuring device shall be adjusted appropriately. A standard speedometer is used to measure and record the actual acceleration value of the test vehicle when it passes through the monitoring area, whilst the speed measuring device of the remote sensing system measures the acceleration of the test vehicle and takes pictures. According to the above method, the tested acceleration is measured 3 times; the value of each measurement is compared with the value of the standard speedometer.

c) Acceleration indication error of speed measuring device is calculated according to formula (9):

$$\Delta\alpha = \alpha - \alpha_0 \tag{9}$$

Where:

$\Delta\alpha$ - Acceleration indication error of speed measuring device, m/s^2;

α - Acceleration indication value of speed measuring device, m/s^2;

α_0 - Acceleration indication of standard speedometer, m/s^2.

7.3.2 Equal-precision comparison method

When the actual detection road cannot meet the test of the experimental vehicle, the equal-precision comparison method can be used to measure the speed and acceleration, that is, the radar-type speed measurement standard device and the remote measurement system speed measurement device are used for comparison detection. In the state of real traffic flow, the radar-based speed measurement standard device and the remote sensing system speed measurement device simultaneously detect vehicles passing through the

δ_{QY} - The indication error of the atmospheric pressure measuring device;

$\overline{Q}_{Yi}$ - The average value of 3 indication values of atmospheric pressure measuring devices, kPa;

$\overline{Q}_{Y}$ - The average value of the indication values of 3 atmospheric pressure measurements of calibration devices, kPa.

7.5.4 Indication error of wind speed measuring device

7.5.4.1 Place the standard anemometer and the calibrated wind speed measuring device at the outlet of the same standard wind speed generator; fix them firmly.

7.5.4.2 Start the standard anemometer smoothly; control the indication values of the standard anemometer to be about 4 m/s, 5 m/s, 7 m/s, respectively. When the wind speed is stable, read the indication value of the calibrated wind speed measuring device. Calculate the indication error of the wind speed measuring device according to formula (14).

$$\delta_{CB} = \frac{H_C - H_B}{H_B} \times 100\% \tag{14}$$

Where:

δ_{CB} - The indication error of the wind speed measuring device;

H_C - Indicating value of the calibrated wind speed measuring device, m/s;

H_B - Indicating value of standard anemometer, m/s.

8 Representation of calibration result

8.1 Calibration data processing

The relative indication error generally retains 2 significant figures.

8.2 Evaluation of uncertainty of calibration results

The uncertainty of the indication error measurement results of the exhaust gas measuring device, speed measuring device, meteorological parameter measuring device, slope measuring device is evaluated according to JJF 1059.1. The uncertainty evaluation example of some parameters is as shown in Appendix D.

Appendix D

Example of uncertainty evaluation of indication error calibration for remote sensing system of vehicle exhaust

D.1 Evaluation of calibration uncertainty of indication error of gas measuring device

D.1.1 Measurement method

In accordance with the requirements of this specification, during the calibration process, a series of standard gases of the same type as the gas measured by the calibrated measuring device are used to calibrate the measurement performance of the calibrated measuring device. The indication error is an important indicator of the measuring device. There are two methods to calculate the indication error in this specification, one is the absolute error and the other is the relative error. According to the requirements of this specification, it analyzes the expanded uncertainty of the absolute error and the relative error of the gas measuring device, respectively.

D.1.2 Measurement model

D.1.2.1 The formula for calculating the absolute error of the indication:

$$\Delta C = \overline{C_i} - C_s \tag{D.1}$$

Where:

ΔC - The absolute indication error of the gas measuring device;

$\overline{C_i}$ - The average value of 3 measurements at the i^{th} calibration point of the gas measuring device;

C_s - The molar fraction value of the standard gas.

D.1.2.2 Calculation formula for relative error of indication:

$$\delta_C = \frac{\overline{C_i} - C_s}{C_s} \times 100\% \tag{D.2}$$

Where:

δ_C - The relative indication error of the gas measuring device.

D.1.8 The expanded uncertainty of the indication relative error of the CO gas mole fraction of the gas measuring device

$$U(\delta)=(4.82\times 10^{-4})/(1.98\times 10^{-2})\times 100\%=2.43\%,\ k=2$$

D.2 Evaluation of calibration uncertainty of speed indication error of speed measuring device

D.2.1 Measurement method

According to this specification, the uncertainty of calibration of the indication error of the speed measuring device at the target speed of 60 km/h is evaluated.

D.2.2 Measurement model

$$\Delta v = v - v_0 \tag{D.4}$$

Where:

Δv - Speed indication error of the speed measuring device, km/h;

v - Speed measurement value of the speed measuring device, km/h;

v_0 - Speed value of standard speedometer, km/h.

D.2.3 Variance formula of indication error

In formula (D.4), v and v_0 are not related to each other, so

$$u_c^2(\Delta v)=u^2(v)+u^2(v_0)+u^2(\delta) \tag{D.5}$$

Where:

$u_c(\Delta v)$ - Combined standard uncertainty, km/h;

$u(v)$ - The standard uncertainty introduced by the resolution of the speed measuring device itself, km/h;

$u(v_0)$ - The standard uncertainty introduced by the standard speedometer, km/h;

$u(\delta)$ - The standard uncertainty introduced by measurement repeatability, km/h.

D.2.4 Evaluation of standard uncertainty

D.2.4.1 Type A evaluation of standard uncertainty

Take the point where the speed value of the speedometer is at 60 km/h. Read

Where:

$u_c(\Delta\alpha)$ - Combined standard uncertainty, m/s^2;

$u(\alpha)$ - The standard uncertainty introduced by the repeatability of acceleration measured by the speed measuring device, m/s^2;

$u(\alpha_0)$ - The standard uncertainty introduced by the standard speedometer, m/s^2.

D.3.4 Evaluation of standard uncertainty

D.3.4.1 Type A evaluation of standard uncertainty

Take the point where the acceleration of the standard speedometer is 2 m/s^2. Read the indication value of the acceleration of the speed measuring device. Repeat 6 times under the same conditions. The measured values are 1.9 m/s^2, 1.9 m/s^2, 2.0 m/s^2, 1.9 m/s^2, 2.0 m/s^2, 1.9 m/s^2.

Average of measured values:

$$\bar{\alpha} = \frac{\sum_{i=1}^{n} \alpha_i}{n} = 1.93\ \mathrm{m/s^2}$$

Experimental standard deviation:

$$s(\alpha) = \sqrt{\frac{\sum_{i=1}^{n} (\alpha_i - \bar{\alpha})^2}{n-1}} = 0.05\ \mathrm{m/s^2}$$

The standard uncertainty caused by measurement repeatability is:

$$u(\alpha) = \frac{s(\alpha)}{\sqrt{n}} = \frac{0.05\ \mathrm{m/s^2}}{\sqrt{6}} = 0.02\ \mathrm{m/s^2}$$

D.3.4.2 Type B evaluation of standard uncertainty

For the uncertainty component introduced by the standard speedometer device, the maximum allowable error of the standard speedometer acceleration is ±0.1 m/s^2, meanwhile the error is uniformly distributed, therefore:

$$u(\alpha_0) = \frac{0.1\ \mathrm{m/s^2}}{\sqrt{3}} = 0.058\ \mathrm{m/s^2}$$

$\Delta\beta$ - The indication error of the slope measuring device, (°);

$\overline{\beta_2}$ - The average value of 3 measurements of the measured slope measuring device, (°);

β_1 - Indicating value of standard electronic level, (°).

D.5.3 Variance formula of indication error

Since β_1 and β_2 are not related to each other, therefore:

$$u_c^2(\Delta\beta) = u^2(\beta_2) + u^2(\beta_1) + u^2(\beta) \qquad (D.11)$$

Where:

$u_c(\Delta\beta)$ - Combined standard uncertainty, (°);

$u(\beta_2)$ - The standard uncertainty introduced by the resolution of the slope measuring device, (°);

$u(\beta_1)$ - The standard uncertainty introduced by the standard electronic level, (°);

$u(\beta)$ - The standard uncertainty introduced by measurement repeatability, (°).

D.5.4 Evaluation of standard uncertainty

D.5.4.1 Type A evaluation of standard uncertainty

$u(\beta)$ is the uncertainty introduced by the measurement repeatability of the slope measuring device. Place the standard electronic level and the measured slope measuring device on the same freely tiltable plane; their center points are on the same straight line. At this time, the standard electronic level and the measured slope measuring device are both reset to zero. It rotates with the straight line of the point as the axis. When the indication value of the standard electronic level is 5° respectively, read the value of the measured slope measuring device at this point. Read the results 10 times. Evaluate according to the normal distribution. Calculate the experimental standard deviation s(v). The measured values are 4.89°, 4.87°, 4.88°, 4.86°, 4.87°, 4.88°, 4.89°, 4.88°, 4.89°, 4.88°.

Average of measured values:

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