Multi-node Test and Calibration of Automotive Chip Oxygen Sensor

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Abstract: The chip oxygen sensor is an important application structure in the vehicle driving process. Currently, the commonly used chip oxygen sensor is a zirconia chip oxygen sensor, which has the advantages of small size, strong temperature resistance, and strong stability according to the parts. This article analyzes the working principle and main classification of the chip oxygen sensor for vehicles. This paper studies the specific application of multi-node automatic detection and calibration system. The author's purpose is to improve the application performance of the chip oxygen sensor for vehicles and improve the stability of the vehicle during driving.

1. Introduction
The EFI engine control system is a very important structure during the normal operation of the car. In this system structure, the chip oxygen sensor is very important. In order to meet the normal operation of the system, we need to do a good job of performance testing and parameter calibration. The purpose of analyzing the correlation between testing and calibration is to improve the efficiency of testing and calibration, and to increase the pass rate of products.

2. Overview of Chip Oxygen Sensors for Vehicles
2.1. Working Principle

![Schematic Diagram of Chip Oxygen Sensor Structure](image)

Figure 1: Schematic Diagram of Chip Oxygen Sensor Structure
At present, the automotive chip oxygen sensors used in automobiles are mainly zirconia chip oxygen sensors. This article takes this component as an example to analyze the working principle. As shown in Figure 1, the sensor contains two zirconia disks for pumping oxygen and measuring. Two zirconia disks and oxygen diffusion barrier form the diffusion chamber of the sensor, which can be used to measure the oxygen volume fraction of automobile exhaust. Among them, the diffusion barrier is used to limit the speed of oxygen entering the diffusion chamber to control the size of the limit current under different oxygen concentrations. The zirconia measuring disc and the ceramic sealing structure form an air reference cavity, which is used to compare the oxygen partial pressure difference between the exhaust gas and the reference gas [1]. At the bottom of the sensor, a resistor paste screen printing and sintering method is used to make a heater on the ceramic diaphragm, which can be used to heat the sensor core to the working temperature. According to the characteristics of ZrO2 material, when it reaches the working temperature (usually ≥650 ℃), two physical processes will occur: (1) Decompose free oxygen ions. The free oxygen ions send oxygen through the ZrO2 disk under the action of a direct voltage, and release oxygen at the anode, which is the action of an electrochemical pump. (2) When there is a difference in oxygen partial pressure on both sides of ZrO2, Nernst voltage will be generated. The specific calculation formula is: \[ V = \frac{RT \ln(P_{O2, a}/P_{O2, dg})}{4F} \]. Where \( V \) represents the Nernst voltage; \( F \) represents the Faraday constant; \( R \) represents the resistance value formed by the conductor after the measuring disc reaches a given temperature; \( P_{O2, a} \) represents the oxygen partial pressure inside the reference cavity structure; \( P_{O2, dg} \) represents the oxygen content of the diffusion cavity structure Pressure.

2.2. Main Classification

2.2.1. Ordinary Sensor

At present, the car's chip oxygen sensor is mainly based on zirconia type sensor, such as Volkswagen, Changan, BYD and many other cars use this sensor, its basic structure is zirconia tube. For ordinary sensors, its composition is relatively simple. That is, the inside and outside of the zirconia tube are covered with a layer of platinum (with a thickness of 1mm-3mm), and the inside of the structure will communicate with the atmosphere. However, the outside of the structure will come into contact with the exhaust gas discharged from the exhaust tube. In addition, a ceramic coating is also applied on the platinum outer layer, and its main function is to avoid the corrosiveness caused by exhaust gas. The detection principle is to use the difference in oxygen concentration inside and outside the tube to evaluate the current operating state of the structure [3].

2.2.2. Hydrogen Sensor

Some electronically controlled gasoline engines (such as Mercedes-Benz, Volvo, etc.) with OBD (on-board diagnostic system) installed in order to obtain the current performance of the converter in real time need to use the hydrogen sensor structure to complete the running status monitoring [4]. Usually these cars will install an oxygen sensor before and after the converter. The oxygen sensor located in front of the converter is mainly used to collect the oxygen content information in the exhaust pipe, which is also the basic condition for air-fuel ratio. Its voltage value will fluctuate from 0.1V to 1.0V. Moreover, under normal circumstances, the voltage value of the oxygen sensor located behind the converter is stable at 1.0V and remains unchanged, which is also a normal parameter in the normal operation of the system. When the voltage value changes relatively large and its voltage value is higher than the voltage of the front oxygen sensor, it indicates that the system engine has oil control problems, and we need to check it carefully [5].

2.2.3. Wide Range Oxygen Sensor

For some engine systems with relatively high oxygen content in exhaust gas, such as Mitsubishi's GDI fuel in-cylinder direct injection gasoline engine and Volkswagen's FSI fuel stratified fuel injection gasoline engine, the maximum air-fuel ratio can exceed 40. During use, the oxygen concentration in
the exhaust gas is relatively high. In this case, a wide range oxygen sensor is needed to complete the concentration detection. Compared with other oxygen sensors, the precision of the internal parts of the wide range sensor is relatively high. It can smoothly capture the oxygen content information in the exhaust gas and calculate reliable application data, thereby providing reliable data support for the selection of NOx purifiers.

3. Multi-node Automatic Detection and Calibration System Analysis

3.1. System Components

![Figure 2: The Basic Composition of A Multi-node Automatic Detection and Calibration System](image)

In the actual structure of the multi-node automatic detection and calibration system, it is mainly composed of a standard oxygen source module, an electric control valve management module, a multi-node gas path tooling module, a node data acquisition module, and a computer management module. In order to ensure the accuracy of the test results during the working process of the system, the standard oxygen source used in the verification process cannot be less than four groups. Moreover, the standard oxygen concentration of each group is different, in order to improve the diversity of detection data collection [6]. Under normal circumstances, standard oxygen source 1 or standard oxygen source 4 are the maximum oxygen concentration and minimum oxygen concentration respectively, and the remaining standard oxygen sources are chosen between the two. We use this to ensure the diversification of the collected data. At the same time, the oxygen sensor installed at the node position is used to collect data and information and control the flow resistance. Generally, the flow resistance should be controlled within 5mm to ensure the reliability of the collected data.

3.2. Analysis of Detection Methods

3.2.1. Heater Resistance

The verification method that is often used when detecting heater resistance is the meter verification method. The specific verification process includes the following steps. Firstly, temporarily unplug the oxygen sensor harness connector. At this time, the oxygen sensor is in a disconnected state, we can use a multimeter to measure the resistance value in the oxygen sensor. We also need to debug the multimeter before the measurement, and then adjust the multimeter to the resistance range measurement after finishing the debugging [7]. Second, use a multimeter to test the resistance value of the circuit and other node positions between the heater terminal and the bonding terminal. Under normal circumstances, the resistance value needs to be between 4Ω and 40Ω, which is also a normal requirement during normal vehicle control system operation. If the resistance value does not meet the requirements, then we need to replace the oxygen sensor at this time. Third, after replacing the oxygen sensor, we need to measure the compliance of the resistance value again. Until the compliance of the resistance value meets the requirements, the structure can be put into use [8].
3.2.2. Feedback Voltage Measurement

Feedback voltage measurement is a very important detection link in the oxygen sensor detection process. When testing it, the commonly used testing method is the introduction method. That is, a thin wire is drawn from the sensor line column, and then the normal working state of the oxygen sensor is restored. Thus, the feedback voltage of the lead wire is measured to determine the compliance of the oxygen sensor. In the specific application process, we need to follow the following application steps.

1. After leading out the thin wire, resume the operation of the oxygen sensor. Besides, make it in a normal working state. At the same time, the engine returns to the normal operating temperature after starting. Sometimes in order to save the time of warm-up, the detection can start when the engine speed reaches 2500r/min. (2) Adjust the multimeter to the voltage range. After finishing the preliminary debugging work, put the test leads on the negative position of the power supply, check the socket and lead wire end, and get the corresponding indication [9]. (3) Start the engine equipment. After reaching the working temperature or the speed exceeds 2500r/min, observe the indication in the multimeter at this time. Simultaneously, the voltmeter pointer will swing between 0V and 1V, and the number of times the multimeter pointer swings within ten seconds is recorded. In the standard state, the feedback voltage of the oxygen sensor will change up and down 0.45V. Meanwhile, the number of voltage changes is more than 8 times. If this requirement is not met, it indicates that there are some potential problems in oxygen sensing, such as surface carbon and structural aging. If there is a problem of carbon deposits on the surface, you can keep the 2500r/min state for 2 minutes before measuring to eliminate the carbon deposits on the resulting surface. Facing the problem of parts aging, we need to replace the aging parts in time, and then proceed to the next stage of measurement work.

4. Perform oxygen sensor node detection, temporarily disconnect the connection line, and use a multimeter to detect the feedback voltage line post and ground connection post. Later, according to the obtained detection value, the working condition of the oxygen sensor is determined, and the damaged parts or the loose terminal are replaced in time. Retest after replacement to improve the reliability of the test results [10].

3.2.3. Sensor Visual Inspection

When inspecting the appearance of the sensor, we can use the observation method and empirical method to complete the inspection work in this link. The specific process is as follows. First, remove the oxygen sensor from the exhaust pipe, check the housing of the oxygen sensor, and check whether the air hole is blocked. At the same time, check the integrity of the ceramic core to see if it is damaged. If there is serious blockage or damage to the ceramic core, then we need to replace it in time. In this way, the stability of the working state of the oxygen sensor structure is improved. Second, check the color of the top part of the oxygen sensor, which is also an important reference for whether there is a problem with the structure. If the top is light gray, the oxygen sensor is currently in normal working condition. If the tip is white, the oxygen sensor is contaminated by silicon and cannot be used anymore, so we need to replace it. If the tip is brown, then the oxygen sensor is contaminated by lead element. Check the contaminated condition. You can continue to use it after cleaning up under normal conditions. But in the case of serious pollution, we need to replace it. If the top is black, then the oxygen sensor has carbon deposits. At this time, we can keep the engine at 2500r/min for 2min to eliminate the carbon deposit on the result surface and confirm the normal use of the oxygen sensor.
3.2.4. Air-fuel Ratio Feedback Control

![Figure 3 Schematic Diagram of Air-fuel Ratio Feedback Principle](image)

As shown in Figure 3, the feedback control of the air-fuel ratio is also one of the most important contents in the testing process. The main control principle is to collect oxygen concentration data with the help of oxygen sensors, and then transmit feedback signals to the ECU control device. If the feedback signal shows that the mixed gas concentration is low, then we can extend the fuel injection time to ensure the air-fuel ratio feedback control effect. Because the whole process has a high degree of relevance to the computer, when testing it, we will use automated testing technology to complete the system running status monitoring, so as to maintain the stability of the system running status.

3.3. Calibration Method Analysis

In the application process of the calibration method, we need to pay attention to the following application content. First, the main system issues a preparation instruction, and each node structure will preheat the heater structure according to the instruction so that it can enter the normal working state. Second, connect the modules to the standard oxygen source 2 and standard oxygen source 3 respectively, and then use a multimeter to detect the pump current. Third, substitute the detection results into the above-mentioned formulas to obtain standard sensor parameter information. In addition, the sensor parameters are stored with the help of database technology, and then they are passed to the standard oxygen source 1 and the standard oxygen source 4, and data collection and calculation are completed by referring to the previous steps. Finally, the data is compared with the standard data to obtain reasonable data information and improve the reliability of the information content.

4. Analysis of Calibration Test Results

Assuming that a standard oxygen source of 15% (minimum) to 35% (maximum) oxygen concentration is used in the experiment, it is substituted into the standard formula and the correlation constant is calculated to determine the error range of the data value. Generally, the error control range of the data is kept within 2%. However, judging from the results of multiple sets of data, in the specific test process, there are large differences between individual oxygen sensors. Moreover, the direct replacement of the oxygen sensor also has some difficulties, which is also one of the issues we need to pay attention to in the follow-up experiments.

5. Conclusion

In summary, the oxygen sensor plays a very important role in the normal work of the car. By adopting appropriate methods for verification and testing, not only can the speed of testing and verification work be accelerated, but also has a positive meaning for improving the accuracy of verification results.
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