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Study on a method of prolonging the life of catalytic combustion sensor

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Abstract. The catalytic combustion combustible gas sensor is restricted by the principle, process, environment and other factors. When it is used in the actual working environment, the output value will drift and the measurement error will increase with the passage of time. The longer the service time is, the more serious the problem of sensitivity degradation will be, until it completely fails. In general, the effective service life of the sensor is only 1-2 years. Based on the conventional detection technology, this paper proposes the constant temperature bridge method based on the programmable constant current source. By reducing the use frequency of the catalytic sensitive element, it can avoid the problem that the sensitivity of the element drops too fast under frequent use, and can effectively extend the service life of the sensor to about one time.

1 Introduction

There are two kinds of sensors for detecting combustible gas carbon monoxide: catalytic combustion and infrared absorption. Manufacturers usually use sensors based on catalytic combustion, but rarely use infrared detection sensors with high price, better stability, high accuracy, strong anti-interference ability, and suitable for harsh environment, less maintenance and long service life. Infrared detection principle sensors are generally regarded as high-end products for detecting combustible gases. However, due to price factors, it is difficult to replace the detection instrument of catalytic combustion principle sensor in practical application and can be popularized. This paper will take the catalytic combustion carbon monoxide sensor as an example to discuss[1].

When detecting combustible gas such as carbon monoxide, the combustible gas burns on the surface of the sensitive element to generate heat to increase the temperature of the sensitive element. As the sensing element is composed of spiral t-wire and catalytic support material attached to the surface, Pt wire is a temperature sensitive material The temperature rise of the sensor will inevitably increase its resistance, and the unbalanced voltage V generated by the bridge reflects the volume fraction of the measured combustible gas. However, there are many problems with this traditional detection method: (1) the detection range is small: stable carbon deposits are formed on the surface of the element during the stable aging treatment of the catalytic sensor during the manufacturing process. When the gas volume fraction is too high, the temperature on the catalytic sensitive element will be

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too high, and the carbon deposits on the surface of the sensitive element will be burned off When the temperature decreases, it will gradually recover[2]; (2) Slow corresponding speed: in the bridge detection method, the output signal of the sensor is generated due to the temperature rise of the sensor and the increase of the resistance value of the Pt wire. Because the temperature change of the sensor has a long time delay, the corresponding time of the signal is long; (3) The service life of the sensor is short: relevant tests show that the higher the working temperature of the catalytic sensor, the faster its sensitivity decays Not only the adjustment period is shortened, but also the service life is shortened accordingly This is because the catalytic support undergoes a recrystallization process under the action of high temperature. The above problems of the catalytic sensor cannot be solved by the manufacturing process of the sensor itself. Instead, the above problems can be fundamentally solved by keeping the working temperature of the catalytic sensor unchanged when detecting combustible gas through new detection methods. This is because the catalytic sensor works at a constant temperature and the physical characteristics of the sensitive element will not change due to the high temperature[3].

2 Principle of catalytic bridge

At present, the commonly used carbon monoxide sensor at home and abroad is a heat sensitive element (also known as a carrier sensitive element during combustion) The detection principle is that the sensing element, compensation element and bridge arm resistance form a Wheatstone bridge Add a constant voltage Since the skeleton of the thermal sensing element is platinum wire material Heating when current flows The temperature is about 500 ℃ When encountering carbon monoxide gas When carbon monoxide gas contacts the surface of the sensitive element, oxidation reaction will occur (also known as "flameless combustion") Generate a lot of heat The temperature of the sensitive element increases, the resistance value increases, and the bridge outputs unbalanced voltage[4], reflecting the concentration of the measured carbon monoxide. The principle of carbon monoxide detection is shown in Fig.1.

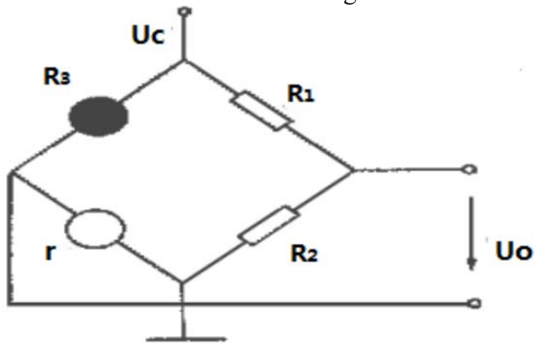

Fig. 1. Measuring bridge of catalytic sensor.

UC - power supply voltage (working voltage of sensor), R3 - thermal sensing element, R- compensation element, R1, R2 - bridge arm resistance, Uo - output voltage.

$$Uo = \frac{U}{R_1 + R_2} * R_2 - \frac{Uc}{R_3 + r} * r \quad (1)$$

$$Uo = Uc(r - R_3) / 2 * (r + R_3) \quad (2)$$

3 Study on a new constant temperature electric bridge

3.1 Principle of constant temperature electric bridge

The constant temperature carbon monoxide detection method is a new detection method that uses carrier catalytic sensing element to keep the sensing element at constant temperature when detecting carbon monoxide gas. Compared with the traditional bridge detection method commonly used at home and abroad, it not only has a large detection range, good stability, Moreover, it has the advantages of good dynamic response characteristics. The dynamic response speed is an important performance index of carbon monoxide detection. It is of great significance for coal mine safety and environmental monitoring to quickly and accurately detect the carbon monoxide in the mine environment[5]. It is conducive to timely monitoring the sudden change state of carbon monoxide in the mine, Reduce or avoid carbon monoxide explosion accidents. The constant temperature carbon monoxide monitoring method is realized through the closed-loop constant temperature control system. It is necessary to study its dynamic characteristics so as to adjust the circuit parameters reasonably. This is very important to improve the stability of the detection signal and improve the dynamic fast response characteristics

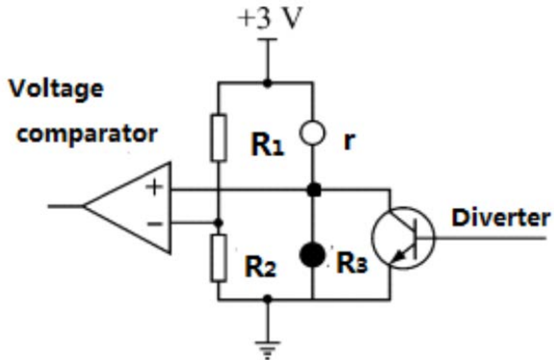

Fig. 2. Constant temperature bridge of catalytic sensor.

Since the change of the temperature of the catalytic sensor will affect the detection accuracy and sensitivity of the gas, the constant temperature detection method is adopted in this paper. The basic circuit of the constant temperature detection of the catalytic sensor is shown in Fig.2. The resistors R1, R2, R3 and the catalytic sensitive element r constitute an electric bridge, and the regulator a constitutes a constant temperature closed-loop control circuit. The working principle is: first, adjust the bridge arm resistance to make the current I flowing through the catalytic sensitive element r equal to its rated working current I0, At this time, the bridge is in a balanced state (R1 * R3 = R2 * r) and the output signal U = I0*r. when combustible gas is detected, the measured gas undergoes catalytic oxidation reaction on the surface of the catalytic sensitive element, generating a large amount of heat, raising the temperature of the catalytic sensitive element and increasing the resistance value. Through the control of the regulator a, the current I is automatically reduced, lowering the temperature of the catalytic sensitive element R and restoring the resistance value to the initial value, The bridge is re balanced. At this time, the output voltage U = I0*r. will decrease, thus reflecting the concentration of the measured gas Therefore, in constant temperature detection, the temperature of the catalytic sensitive element is always kept constant, which effectively reduces the use frequency of the catalytic sensitive element[6-7].

Therefore, the design of constant temperature detection bridge is the key to reduce the use frequency of catalytic sensitive elements. Here, the microprocessor chip, programmable current source and the above Wheatstone bridge are used to form a closed-loop feedback system to force the sensitive elements and reference elements to maintain a balanced state, so that the sensitive elements can work at a constant temperature. The detection loop compares the temperature of the sensing element with the temperature of the reference element. When the carbon monoxide gas in the environment burns on the surface of the sensing element, the temperature of the sensing element will rise rapidly, causing the bridge to lose balance[8]. After the closed-loop feedback system composed of the microprocessor chip detects the deflection signal, it outputs the control signal to control the programmable current source, and reduces the current I through the shunt to "correct" the offset bridge, So that the loop operates in the oscillation of offset / correction repeatedly. The temperature of the sensitive element fluctuates in the constant temperature zone in the form of a small sawtooth wave. The temperature difference of this fluctuation is very small, only a few tenths of a degree. Basically, it can be considered that the temperature of the reference element and the sensitive element are equal[9].

3.2 Design of constant current source system

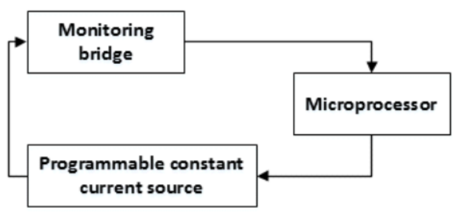

Fig. 3. Feedback diagram of constant temperature bridge system.

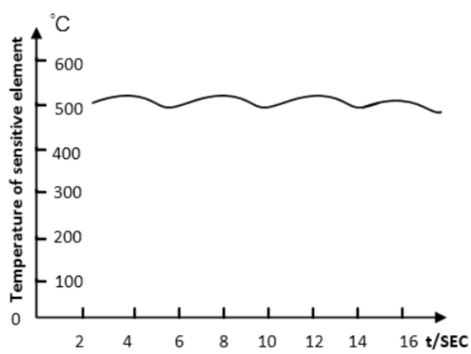

Fig. 4. Constant temperature holding diagram of sensitive element.

Lm4c123 processor is selected to control the programmable constant current source, read the bias voltage of the bridge, and monitor the state of the bridge in real time. When the bias voltage U0 of the bridge is greater than 0, it indicates that there is a certain concentration of CO gas in the environment[10]. The processor immediately controls the constant current source to reduce the current I until the temperature of the sensitive element and the reference element are the same, and the bridge is balanced. The gas concentration is calculated from the current change ΔI. The pseudo code is as follows:

```
Void Monitor(short  Voltage)
    {
    Switch(State)
    {
      Case Init:
      Default:
```

```
      I_Val=I_Init;//Constant current source current gives initial value
      State=ChekState;//Switch to monitoring status
    Break;
    Case ChekState://Real time monitoring of bridge voltage
       while(Voltage >VL)//Judge that the bridge voltage is greater than the set minimum threshold
       {
          SetCurrent(I_Val);//Set the current of programmable cross current source
          wait(1);//Wait 1s
          I_Val--;//Decrease the current value
       }
         State=Handle;
    Break;
    Case Handle:
      SendToSensor(I_Val);//Send to the sensor MCU, and the sensor MCU calculates the gas
concentration
      State=Init;//Switch the initial state and start the next round of monitoring and adjustment
     Break;
  }
  }
```

4 conclusion

The market share of catalytic sensors determines that electrochemical technology is irreplaceable. The design of the constant temperature bridge is mainly to add a constant temperature control unit to the sensor system to convert the voltage signal and the gas concentration signal of the detection bridge into the current signal and the gas concentration. This conversion brings about the increase of the service life and the sensitivity of the sensor. This paper is of great significance to promote the innovation of electrochemical sensor technology.

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