ISSN: 2518-0215, Volume 6, Issue 2, June, 2021

Application and Function of Methane Gas Detection in Coal Mine Engineering

Ke Zhou
Hydrogeological Exploration of China Coal Geology Bureau, Handan, 056004, China

Abstract: In the process of China's coal mine engineering, underground coal mining will encounter gas from the coal body. This kind of gas is usually called mine gas, and its main components are methane, other hydrocarbons and carbon dioxide. The disaster of coal mine gas directly restricts the safety production of coal mine. In the past ten years, there are nearly 70 explosion and accidents caused by coal mine gas. Many accidents occur because that the concentration of coal mine gas is not detected correctly, which leads to gas explosion, causing a large number of casualties, and damaging underground production and safety facilities, and affecting the normal production progress. It can be said that in the process of China's coal mine engineering safety work, the mine gas problem has always been a key and difficult problem. At present, China's coal mine gas problem has been widely valued by the State Coal Mine Safety Supervision Bureau. Therefore, in order to better control the coal mine gas disaster, it is necessary to fully analyze the effective technical application of gas detection of the main components of coal mine gas in coal mine engineering. That is, to detect the main component of methane in coal mine gas, and analyze the concentration of methane gas in coal mine engineering. It also has a certain guiding role for the effective application of coal mine methane detection technology.

Keywords: Methane gas; Gas detection; Coal mine engineering; Gas hazard

1. Introduction

Gas disaster is the main problem leading to coal mine production safety accidents, and methane is the main component of gas, so in a narrow sense, the common coal mine gas mainly refers to methane, and the detection of coal mine gas is mainly for methane detection. Methane is essentially a colorless and odorless gas that can be burned and exploded. For human beings, methane can affect the normal respiratory function and cause asphyxia. In essence, methane is a kind of gas that is easy to diffuse. Its diffusion speed is 1.34 times that of air, and its permeability is 1.6 times that of air. Therefore, it often appears in the cavity of roadway roof. Moreover, the chemical property of methane itself is not active, it hardly produces biochemical compounds with other substances, and it is also difficult to dissolve in water. As far as the concentration of gas is concerned, when the volume percentage is between 5% and 16%, it will directly cause gas explosion when encountering high temperature fire source, and when the volume percentage is between 9.1% and 9.5%, the explosion power is the strongest. Generally speaking, methane gas detection applied in coal mine engineering is mainly used to timely know the situation and changes of methane concentration in coal mine environment, so as to ensure the safety of coal mine production according to the rules and regulations of coal mine engineering safety production. At present, the common methane gas detection methods are mainly divided into catalytic combustion method, thermal conductivity method, optical interference method and non dispersive infrared spectroscopy according to the differences of physical and chemical properties. In the process of studying different principles of methane detection methods, we can better understand the application and environmental conditions of different gas detection methods in coal mine engineering, so as to better explore the applicable methane gas detection methods in different situations, and ensure the production safety of coal mine engineering.

2. Common Methane Gas Detection Methods and Their Functions

2.1. Catalytic combustion method

The catalytic combustion method mainly uses the catalyst to reduce the ignition temperature of methane to 200 ℃ - 400 ℃. Generally speaking, the initial working temperature of this catalytic element is about 400 ℃. When the methane in the environment diffuses into the gas chamber, it will burn in the form of flameless under sufficient oxygen conditions. The heat generated by combustion will cause the temperature of the coil in the catalytic element to rise, increase the resistance and cause the change of electrical signal. In this way, the concentration of methane in the environment can be detected by measuring the change of resistance. At present, many places are also adding different proportion of catalyst to adjust the catalytic activity. The advantage of this method lies in its relatively high measurement accuracy, fast response speed and long service life. At present, it is a common technical form among methane gas detection methods in China's coal mine engineering. This method is also used to build a widely used catalytic combustion gas sensor. However, this methane gas detection technology is mainly suitable for methane gas with concentration between 0% and 4%. It is difficult to detect methane gas for a long time under harsh conditions. Moreover, when the catalyst on the surface of the element contacts with non combustible gas, there will be reaction and it will lead to catalyst poisoning.

2.2. Thermal conductivity method

The thermal conductivity method is mainly based on the thermal conductivity of methane and air, which respectively is 0.029 and 0. 024. Thus when the sensor is heated by current, the sensor can reach a certain temperature level. When methane enters the air chamber, the temperature of the sensing element will drop because the heat dissipation capacity of methane itself is higher than that of air. The resistance value decreases, which leads to the change of output voltage. At this time, Wheatstone bridge can be used to measure the tissue change and obtain the current concentration level of methane gas. This method is mainly applied to the detection of high concentration of methane gas. Generally speaking, the range of high concentration of methane gas is maintained between 4% and 100%. However, the detection accuracy and sensitivity of this method are easily affected by many factors, such as the temperature of the sensitive element, the temperature of the environment, humidity and so on. Once the temperature of the sensitive element is abnormal due to the external environmental conditions, the accuracy of the measurement will be affected. Therefore, in order to reduce the measurement uncertainty caused by various factors in the detection process, it is necessary to compensate the application of this method in the form of software or hardware. Generally speaking, the constant temperature detection technology of variable current source will be used to replace the constant current detection of constant current source, so as to better maintain the temperature of sensitive elements, understand the thermal conductivity through the current change value, and detect the concentration of methane. Some scholars also use neural network algorithm to carry out fitting analysis on the nonlinear error caused by temperature change to realize temperature compensation and calculate the methane concentration after compensation. The heat conduction gas sensor based on the thermal conductivity method is often used in conjunction with the catalytic combustion sensor, so as to better adapt to the detection needs of different concentrations of methane.

2.3. Optical interferometry method

The main theoretical base of optical interferometry is that the refractive index of methane and air are different, and the path of light in the two gas media is also different. Therefore, it will cause the interference pattern to move, which can be known by observing the offset. The refractive index level of light in the gas changes and is related to the concentration level of methane. That is to say, the movement path and optical path difference of light in different gas media will cause the interference pattern to move, and the offset has a good linear relationship with the gas concentration, which is applied to the detection of gas concentration. Interference gas sensor constructed based on this principle uses Michelson interferometer to divide the light from the same light source into two beams. After these two beams of homologous light are transmitted through methane and reference gas, because different concentrations of methane will cause different refractive index, the optical path difference of two beams of light will be affected and the two beams will form interference fringes. And the information related to gas concentration is displayed in the fringes, and the gas concentration is calculated through the change of interference fringes. However, for carrier catalysis, the application of optical interferometry has higher accuracy, wider measurement range and better stability. However, in the practical application of optical interferometry, there are higher requirements for the design of interference system and the acquisition of CCD signal, which leads to higher cost and complex structure, It is suitable for large-scale detection environment. At present, many coal mine methane gas detection in the application of optical interference method set the initial interference fringe through the construction of optical interference methane detector, and through the increase of compensation prism or plane mirror and the base of 55 degrees angle after adjustment. However, because the detection of methane concentration needs to read the scale position of the stripes to calculate the specific concentration, there is certain subjectivity in the reading process, making it difficult to use the objective standard to standardize the reading of the scale position.

2.4. Non dispersive infrared spectroscopy method

In the application process of infrared absorption spectroscopy, the selective absorption of gas molecules can be expressed as different gases. When the gas molecules absorb different wavelengths of light, they will cause the energy attenuation of specific wavelengths of light and produce absorption spectra. Therefore, generally speaking, the gas concentration level will be known by detecting the change of the transmitted light intensity or the reflected light intensity of the gas, Because each kind of gas molecule has specific absorption spectrum characteristics, the light intensity will change after absorption. When the matter is irradiated by the infrared beam, it will absorb part of the light energy and convert it into its own kinetic energy, producing molecular vibration energy level and rotation energy level, so as to realize the transition from the ground state to the excited state. In the spectral lamp, methane will have a strong absorption peak at 3.33 um, and the absorption level is closely related to the concentration level of methane gas itself. Therefore, in the detection process, we can know the concentration of methane gas by measuring the attenuation level of infrared light signal. The application of this method has high selectivity, because each kind of gas has different characteristics of infrared absorption frequency, and the use of optical signal detection. The existing interference signal is small. Once the concentration changes, it can respond immediately. It has high sensitivity, and is not easy to be affected by harmful gases. But correspondingly, if the absorption level is very weak, the signal will hardly appear attenuation phenomenon, resulting in large error. At present, the application of infrared absorption spectroscopy is to correct the phenomenon of overlapping absorption by introducing neural network multi parameter model and least square algorithm, so as to reduce the nonlinear error caused by temperature, humidity, pressure and other factors. After algorithm compensation, the gas concentration measurement results have higher accuracy and stability.

3. Application of Methane Gas Detection in Coal Mine Engineering

Based on the analysis of the influence of coal mine environment on methane detection technology, through the comparative study of coal mine underground technology application, it is found that catalytic combustion method uses the combustible characteristics of methane and is suitable for detecting methane with less than 4% volume fraction, but not suitable for the underground environment with low oxygen concentration, high methane concentration or sulfur-containing gas; the thermal conductivity method is suitable for detecting methane with volume fraction of more than 4% by using different characteristics of air thermal conductivity with different concentrations of methane, and is not suitable for underground environment such as low methane concentration and high carbon dioxide concentration; light interference method, which uses the different characteristics of the refractive index of the air containing different concentrations of methane, is suitable for most of the underground environment, but not suitable for the underground environment with high concentration of carbon dioxide; infrared spectroscopy is suitable for most underground environments because of the selective absorption of methane gas. The non dispersive infrared spectroscopy is interfered by water vapor and alkane gas, so it needs to optimize the algorithm to reduce the error.

From the application of several common methane gas detection methods in coal mine engineering, many detection methods based on optical devices and principles have a wider range of measurement, and can realize full range measurement, with higher relative detection accuracy, faster response speed and higher selectivity and continuous measurement. For example, optical interferometry method and dispersive infrared spectroscopy method have good application effect. At present, in the gas detection system widely used in domestic coal mine engineering, the main applied catalytic combustion has the shortcomings such as the sensor is relatively narrow in the detection range, and the sensitive element is easy to poisoning and aging, and its response speed is relatively slow, basically can only carry out single point measurement. But it also has certain advantages. That is, the catalytic combustion sensor mainly adopts the sensor module pediatric design, so it will be more convenient in maintenance, and its volume is relatively small and the safety level is higher. In the process of analyzing the principle and process of catalytic combustion probe, the components of catalytic combustion method will also have higher stability and anti medium toxicity. In the aspect of output linearity, there will also be a large increase, which is more suitable for the detection of methane gas in severe environment.

4. Conclusion

In general, although the methane detection in China's coal mines basically meets the daily detection needs of coal mines in terms of sensor technology and spectral absorption technology, facing the complex application environment of high temperature, high humidity, strong electromagnetic interference and mixed gas interference in coal mine, it is necessary to strengthen the practical application effect investigation of various methane gas detection technologies in coal mine according to different detection application scenarios, Therefore, it can achieve the rapid quantitative detection of methane gas in the full range, and provide basic support for the effective prevention of disasters and secondary disasters caused by coal mine gas overrun.

References

[1] Liang Yuntao, Chen Chengfeng, Tian Fuchao, Wang Jingyan. Methane gas detection technology and its application in coal mine. Coal Science and Technology. 2021, 49(04), 40-48.

[2] Cao Guojian. Research on the application of toxic and harmful gas detection alarm in sewage treatment plant. Chemical Engineering Design Communications. 2020, 46(09), 164-166+173.

[3] Zhu Jie, Chen Kang, Zhao Sihai, Long Feihu, Jian Yan. Methane gas alarm verification precautions and uncertainty assessment of measurement results. China Standardization. 2019, (15), 165-167+172.

[4] Yu Xin, Li Lei, Zhao Jing, Wang Yiding. Development and test of multi-parameter compensation mid-infrared methane detector. Acta Photonica Sinica. 2019, 48(06), 97-105.

[5] Guo Yanbao, Liu Chengcheng, Wang deguo, HE renyang. advances in the development of methane sensors with gas-sensing materials. Chinese Science Bulletin. 2019, 64(14), 1456-1470.