Original Research Article

Research on intelligent monitoring technology for safe operation of gas pipeline

Xiaolong Ma[1,2,3,4], Gang Gao[1,2,3], ShigongYu[1,2], Han Xu[5]

1 SINOSTEEL MAANSHAN GENERAL INSTITUTE OF MINING RESEARCH CO.,LTD, Anhui Ma 'anshan, 243000, China

2 National Key Laboratory of Mining Safety and Disaster Prevention of Metal Mines, Ma 'anshan, Anhui, 243000 , China

3 National Engineering Research Center for Efficient Recycling of Metal Mineral Resources, Ma 'anshan, Anhui, 243000, China

4 Anhui University of Technology, Anhui Ma 'anshan, 243000, China

5 Ma 'anshan City Yushan District Emergency Management Comprehensive Law Enforcement Brigade, Anhui Ma 'anshan, 243000, China

Abstract: In the huge and complex energy network system, gas is the main by-product produced in the process of coking, ironmaking and steelmaking in metallurgical enterprises. Gas pipelines are laid crisscrossly in every corner of metallurgical enterprises. The gas produced by blast furnace, converter and coke oven is continuously transported to the production areas such as gas holder, sintering, pellet, hot rolling and coke oven, which ensures the normal operation of metallurgical production process and the stable development of enterprises. However, due to the special properties of gas, such as poisoning, ignition and explosion, once the gas pipeline fails and leaks during operation, it is like burying a ' time bomb ', which is likely to cause serious safety accidents. It poses a great threat to the life safety of employees, the normal operation of production equipment and economic benefits. Therefore, this paper analyzes the challenges faced by the safe operation of gas pipelines, and expounds the intelligent monitoring technology for the safe operation of gas pipelines.

Keywords: Gas pipeline ; Safe operation ; Intelligent monitoring ; Technology

1. Introduction

With the wave of science and technology rolling in, new technologies such as the Internet of Things, big data and artificial intelligence are emerging and changing with each passing day, which is also the process of their rapid iterative upgrading. The application of new technologies has begun to transform many traditional industries. These advanced technologies have also entered the pipeline inspection industry with their own influence, which not only greatly improves the speed and accuracy of detection, but also greatly improves the mastery of the internal state of pipeline equipment. Among them, for the gas pipeline, as the ' lifeline ' of the development of iron and steel metallurgical enterprises, its normal operation is related to the development of iron and steel metallurgical enterprises. Therefore, this paper starts with the safe operation of gas pipelines, expounds the relevant background knowledge through investigation and analysis, and combines the current development status of intelligent monitoring technology. Based on this, the intelligent degree of related new technologies is analyzed and studied.

Challenges to the safe operation of gas pipeline

1.1. Management level

Although we are trying our best to ensure the safe operation of gas pipelines in our daily work, there are still many thorny problems to be solved for various reasons. The entire coverage of the gas pipeline system is very wide, and not a single unit department can complete the work, involving various types of subjects, all aspects of the unit organization, so there are considerable difficulties in the entire management coordination process. For the managers, it is necessary not only to coordinate the interests of all parties, but also to try to balance the interests of all parties. On this basis, it is necessary to formulate a set of effective, fair and reasonable management systems and measures applicable to all departments. These are very difficult problems. Not only that, but also the need to manage the relevant personnel to maintain a clear mind at all times, always maintain a sense of responsibility for all personnel. However, the hidden dangers in reality are very terrible. Due to the complex relationship of interests between some units and the unclear attribution of responsibilities, there are many shortcomings in the safety management of gas pipelines in this part.

1.2. Impact of natural disasters

The safety of gas pipeline operation is also seriously affected by natural factors. Typical geological disasters such as earthquakes, land subsidence and landslides will cause damage to underground gas pipelines. The strong pulse-type seismic wave generated by the earthquake will impact the pipe orifice, resulting in the damage of the sealing structure of the pipeline interface, and the dislocation, disconnection or fracture of the pipeline interface. Ground subsidence will cause the pipeline to bear uneven stress, resulting in pipeline bending, deformation and even rupture. Landslides may bury or squeeze pipelines, causing pipeline damage. In addition, periodic climatic factors such as changes in air temperature will cause alternating strains in the pipeline due to cold shrinkage and thermal expansion, continuously loss the joint parts of the pipe fittings, cause initial damage of small cracks, further reduce the stability of the entire pipe network structure, and shorten the life of the pipeline. At the same time, the complexity and diversity of the soil lead to the existence of irregular load dynamic strain, combined with harsh climate and temperature changes and other factors, which will affect the occurrence of pipeline fracture and corrosion and other problems, so that the pipeline is affected by corrosion. The scope of damage is wider, which leads to an increase in the safety and instability of the pipeline.

1.3. Production environmental impact

The production environment of metallurgical enterprises is complex and changeable, which poses many threats to the safe operation of gas pipelines. In the process of high temperature smelting, the ambient temperature around the pipeline is high, and the long-term high temperature environment will change the material properties of the pipeline, such as reduced strength and poor toughness, which is easy to cause problems such as deformation and fracture of the pipeline. At the same time, a large amount of dust and corrosive gas will be produced in the metallurgical production process. These substances will adhere to the surface of the pipeline or invade the interior of the pipeline, causing corrosion and wear to the pipeline and shortening the service life of the pipeline. In addition, vibration will be generated during the operation of production equipment in metallurgical enterprises. Long-term vibration may lead to loosening of pipeline connection parts and cracking of welds, which will affect the safe operation of pipelines. Moreover, material handling, equipment maintenance and other operations in the enterprise may also cause external collisions on the gas pipeline and cause pipeline damage.

2. Intelligent monitoring technology for safe operation of gas pipeline

2.1.Sensing technology

The distributed optical fiber acoustic sensing (DAS) system has superior performance. It can accurately locate the accurate position within 10 meters by collecting the continuous vibration signals around the pipeline, and can grasp the safety status of the pipeline at any time. In addition to the installation of distributed optical fiber acoustic sensing (DAS) system, the use of distributed optical fiber temperature sensing (DTS) during pipeline operation can also realize real-time monitoring of the temperature change of the pipeline itself. When gas leakage occurs, it will be found quickly and alarmed to facilitate subsequent maintenance work.

In addition to the above-mentioned optical fiber sensing method, there are many other methods of using physical principles for measurement and control, such as : At present, the more mature MEMS sensor has the advantages of small size, low power consumption and low price. It can be deployed in large quantities on the pipeline in the production process, and can use the MEMS sensor to establish a dense monitoring network along the pipeline. Different MEMS sensors play different roles. Among them, MEMS accelerometers are used for pipeline vibration, and MEMS pressure sensors are used to monitor the pressure changes of pipelines. The coordinated operation of various sensors makes pipeline monitoring more accurate and reliable. The smart ball sensor is an advanced sensor developed specifically for pipeline internal monitoring. It can flow with the medium inside the pipeline, like a ‘ pipeline guard ‘ freely passing through the pipeline. The smart ball is equipped with various advanced sensors to measure the wall thickness, corrosion degree and geometric deformation of the pipeline. It runs regularly in the pipeline according to a fixed schedule, and obtains a large amount of specific information about the internal situation of the pipeline. Therefore, it can directly and effectively reflect the internal situation of the pipeline, which is conducive to early detection of pipeline hidden dangers and early maintenance decision-making.

2.2. Leakage detection and location

For the operation of gas pipelines, gas leakage is a very serious and non-negligible hidden danger. It is also indispensable to use various advanced technical means in the intelligent monitoring system to realize the early identification and accurate positioning of gas leakage. The purpose is to ensure the safe and stable operation of the pipeline. Pressure wave detection method is a major technology of intelligent monitoring system. When the gas pipeline leaks, a negative pressure wave is formed in the pipeline, and it is transmitted in both directions along the upstream and downstream of the pipeline. Therefore, a high-precision pressure sensor is installed at both ends of the pipeline. By measuring the time difference between the two pressure sensor signals to which end the negative pressure wave at any position of the pipeline is first transmitted, the location of the leakage can be accurately determined. Using this method to detect the leakage of gas transmission lines has the characteristics of high efficiency and high positioning accuracy, which is especially suitable for the leakage detection of gas transmission lines.

The use of acoustic wave detection method can also achieve the purpose of gas leakage detection. When a gas leak occurs, a certain ultrasonic signal will be generated. The intelligent monitoring system is used to install it on the pipeline to collect the ultrasonic signal in the pipeline. Due to the difference in the acoustic wave signals generated by different sizes of leaks, the size of the leak can be determined after analyzing different signal characteristics. The distributed optical fiber acoustic sensing technology realizes the long-distance, continuous and real-time monitoring of the sound waves propagating in the pipeline, improves the sensitivity of leakage detection, and can monitor the leakage of the subtle parts of the pipeline, so that the micro-leakage has nowhere to hide.

In addition, the detection methods commonly used in intelligent detection systems include gas concentration monitoring methods, and the corresponding position sensors are arranged along or near the gas pipelines of iron and steel metallurgical enterprises. In addition, the concentration value of air gas is detected on site, and the laser methane detection method is commonly selected to achieve high-precision long-distance measurement under its working state, and it has high measurement sensitivity (ppm level). According to the change trend of gas concentration detected by each position sensor, the specific location of leakage and the corresponding leakage amount can be deduced. The intelligent monitoring system does not use a single way to carry out leak detection work, but based on multi-source information fusion technology, and uses different detection methods to obtain information, and combines them to analyze, which can effectively improve the accuracy and reliability of leak detection. If the system finds the gas leakage problem, it will immediately alarm, and will accurately locate the leakage position on the map, and will immediately start the emergency plan to deal with the gas leakage accident, so as to minimize the harm and loss caused by the accident.

2.3. Early warning of external force damage

A very important reason for pipeline accidents is third-party construction damage. After the application of the intelligent monitoring system, the potential risk sources can be accurately detected by the vibration signal detection function of the system, and the early warning can be carried out in time to prevent the safety accidents of the third-party construction accidentally damaging the pipeline. The intelligent monitoring system must first collect the vibration signal of the pipe gallery foundation along the pipeline. Accelerometers and optical fiber vibration sensors are scattered in different locations. They are like loyal guards around the pipeline, constantly detecting the vibration of the environment around the pipe gallery foundation. When it is necessary to accurately detect the vibration signal generated by the external equipment, the sampling frequency is generally set to be greater than or equal to 100Hz.When the vibration signal is collected, it is necessary to enter the stage of vibration feature analysis.The vibration generated by different types of engineering equipment has different frequency characteristics and time domain characteristics. For example, the main vibration caused by the excavator is medium and low frequency vibration (about 10 ~ 100Hz). This kind of vibration intensity is large, but the action time is short. The vibration caused by the pile driver shows a certain periodicity, the vibration frequency is low but the energy is large; the vibration frequency of hand-held machines such as electric picks is high (greater than 100Hz), but the amplitude of vibration is not large. Therefore, it is necessary to distinguish the signal types by different signal characteristics of different frequency bands. Through the analysis of the spectrum characteristics, time domain characteristics and energy distribution of the system, the corresponding types of work can be determined. Behavior pattern recognition is an important step in intelligent monitoring and a major part of behavior pattern recognition.This is through the application of advanced machine learning technology, and then use the vibration signal, using this method to deeply mine the data source, and then effectively separate the construction vibration and non-construction vibration (such as : traffic vibration, seismic vibration). When it is found that there may be construction vibration, it can immediately send an alarm to the management personnel, and immediately pay attention to the current construction situation. Finally, the intelligent early warning function is to make judgments based on various factors such as the size of the vibration, the distance from the pipeline, and the type of vibration. At the same time, the emergency communication program is started, and the stop signal can be automatically sent to the construction equipment if necessary to ensure the safety of the pipeline.

3. Conclusion

In the guarantee system for the safe operation of gas pipelines, intelligent monitoring technology is like a solid cornerstone, providing strong support for it. However, the wave of scientific and technological development never stops, and the environmental conditions are also in dynamic changes, which makes the existing

intelligent monitoring technology face new challenges and opportunities. Therefore, it is urgent to continue to carry out relevant research and continuously promote technological innovation. Looking forward to the future, we need to work from multiple dimensions. On the one hand, we should focus on strengthening basic research work, deeply explore the application principles and potential laws of intelligent monitoring technology in the field of gas pipelines, lay a solid theoretical foundation for the long-term development of the whole industry, and promote the industry to a new height. On the other hand, actively explore new application modes, combine advanced Internet of Things, big data, artificial intelligence and other technical means, optimize the function and performance of intelligent monitoring systems, and improve their application effects in actual scenarios. Through these efforts, a more reliable and more solid guarantee system is built for the safe and stable operation of gas pipelines.

About the author

XiaolongMa (1988-), male, Han nationality, graduate student from Zhangjiakou City, Hebei Province, senior engineer, SINOSTEEL MAANSHAN GENERAL INSTITUTE OF MINING RESEARCH CO.,LTD, Anhuan Institute, Ma ‘anshan City, Anhui Province, 243000, deputy director, research direction : oil and gas safety.

References

[1] Shouwuzhou, Yu Guangrong, Lu Xiaofeng. Analysis and prevention and control measures of acid condensate water in blast furnace gas pipeline [J].Industrial safety and environmental protection, 2025,51 (06) : 36-39.

[2] Huang Jianxiong. Study on safe operation management of gas town gas in medium and low pressure cities [J].Chemical Design Communication, 2022,48 (11) : 185-187.

[3] Zhang Wei, Research and application of key technologies for intelligent monitoring of elevator Internet of things. Guangdong Province, Guangzhou Special Mechanical and Electrical Equipment Inspection and Research Institute, 2021-08-27.

[4] Chelixin. Problems and Countermeasures for Safe Operation of Urban Gas Pipeline Network [C] / / Thesis Collection of the 2007 Meeting of the Specialized Committee of Transmission and Distribution of City Gas Branch of China Civil Engineering Society. Beijing Gas Group Co., Ltd. ; 2007 : 17-21.