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Current Status of Belt Conveyor Fault Monitoring

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Abstract. The belt conveyor is an important part of the coal mine transportation system, and the state detection system is the core to ensure its safety and reliability. Traditional condition monitoring methods are difficult to achieve comprehensive and effective monitoring. Distributed acoustic fiber optic sensing system (DAS) can achieve long-distance and high spatial resolution condition monitoring, and can accurately extract vibration or acoustic signals at any position along the optical fiber. Due to this unique advantage, it has attracted more and more attention. Due to the complex working environment of the mine belt conveyor, external interference will affect the fault identification. Therefore, it is necessary to study efficient signal processing methods to improve the accuracy of fault identification. Based on this, this paper introduces the main faults of the belt conveyor and the current status of fault detection of the belt conveyor at home and abroad.

Keywords. Belt conveyor, distributed optical fiber, status detection, fault diagnosis

1. Introduction

Belt conveyors play an irreplaceable role in the transportation of the coal mine industry, especially for the growing demand for large belt conveyors such as long-distance, large-capacity and high-speed belts. Due to long-term high-load and high-speed operation, belt conveyors are prone to various failures, such as idler damage, belt breakage, belt tearing, deviation, slipping, coal piles, and fires. These failures may pose a serious threat to the safety of personnel and equipment, and will directly affect coal mine production and cause economic losses [1]. Therefore, it is of great significance to research and develop the condition monitoring technology suitable for belt conveyor to improve its stability and reliability. Such technology can help early detection of abnormal operating conditions of belt conveyors and early warning of faults, thereby reducing the risk of accidents, ensuring the safety of personnel, and reducing economic losses in production. The research in this field is one of the core technologies that need to be focused on in the coal mining industry. It aims to improve the monitoring system of the belt conveyor to cope with the characteristics of long distance, large volume, and high-speed belt, so that it can better meet the needs of the coal mining industry [2].

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2. Main Faults of Belt Conveyor

Mine belt conveyors generally adopt a trough structure, which is mainly composed of a head (including motors, transmissions, rollers, etc.), a fuselage (including rollers, racks, etc.), a tail, conveyor belts and auxiliary devices (such as braking devices, cleaning devices, etc.). Among them, roller failure and frame failure are the main mechanical failures, accounting for more than 60% of the total number of failures. The idler roller plays a key role in the structure of the belt conveyor, and its working condition directly affects the service life of the conveyor belt and the smooth operation of the belt conveyor. However, in the actual operation site, foreign matter such as moisture and coal dust will corrode the bearing of the idler roller and affect its flexible rotation. In this case, if the surface of the idler roller is adhered by the material, the resistance distribution will be uneven, which may cause deviation failure. Even when the idler roller is stuck and does not rotate, the continuous sliding friction will cause the temperature to rise, and once the idler is stopped, a fire accident may occur [3]. On the other hand, the frame is the basic component of the belt conveyor, and its quality and installation process directly determine the safe and stable operation of the belt conveyor. The failure of the rack mainly refers to the deformation of the rack, which can easily lead to deviation faults, which in turn lead to secondary accidents such as conveyor belt wear and slipping. Therefore, in the actual coal mine production and transportation process, the inspection of the frame is an indispensable link. In order to ensure the safe operation and prolong the service life of the belt conveyor, it is necessary to regularly maintain and inspect the idler rollers and the frame. In addition, the development of condition monitoring technology suitable for belt conveyors, early detection of signs of failure and early warning are also important measures to improve system stability and reliability. To sum up, only by fully paying attention to the operation status of these key components can the belt conveyor play its irreplaceable role in coal mine production.

3. Current Status of Belt Conveyor Condition Monitoring at Home and Abroad

Fault diagnosis is defined as determining the type, location, and degree of the fault based on an appropriate assessment of the fault. Condition monitoring is an important part of fault diagnosis, which involves identifying or early warning of faults in the system and obtaining useful information about the fault. Early detection of faults in belt conveyor systems can minimize downtime and maximize production. At present, the state monitoring methods of domestic belt conveyors mainly include: manual inspection, electric sensor, inspection robot, etc.

3.1. Manual Inspection

Manual inspection relies on experienced technicians to conduct regular inspections, use handheld devices to measure noise or temperature, and perform necessary maintenance activities. This process first requires a lot of manpower and professional knowledge: inspectors must have strong professional knowledge and rich on-site experience in

conveyor maintenance, because this kind of inspection requires careful observation and judgment. Secondly, the labor cost is relatively high, because the professional background and experience of technicians need to be paid accordingly. Moreover, if there is a component failure, it may cause serious damage to the surrounding infrastructure, and at the same time, the inspectors need to be in a dangerous environment, which increases the safety risk. Therefore, there are problems of low efficiency and potential safety hazards in manual inspection [4].

3.2. Electric sensor monitoring

Electric sensor monitoring is widely used in conveyor systems because of its ease of installation. However, in the special environment of underground coal mines, in order to prevent gas explosions, intrinsically safe sensors must be used. And battery-powered sensors require regular maintenance, which can add significantly to operating costs. Furthermore, given the typically large scale of conveyor systems, with the high number of rollers, the belt length can exceed 5 kilometers and the number of rollers can be in the tens of thousands. To achieve full-coverage real-time monitoring, it is necessary to arrange a large number of explosion-proof sensors and complex power supply equipment, which increases the difficulty of maintenance. Therefore, electrical sensor monitoring can face high investment and maintenance costs in large conveyor systems. Considering various factors comprehensively, it is very important to choose the appropriate monitoring method to improve the stable operation of the belt conveyor and reduce the production cost.

3.3. Inspection Robot Monitoring

As an unmanned and intelligent monitoring method, the inspection robot has potential advantages and can realize real-time monitoring of the operating status of the belt conveyor. Its autonomous inspection function can reduce manual intervention and improve monitoring efficiency and reliability. However, inspection robots also have some limitations. First of all, since the inspection robot needs to move according to the predetermined inspection path, continuous state monitoring cannot be realized. Secondly, the mechanical and electrical structure of the robot is relatively complex, and the installation layout in the coal mine environment is greatly affected by the roadway terrain, which may lead to limited monitoring coverage. Moreover, the maintenance cost of the robot is relatively high, requiring regular maintenance and maintenance, especially in the harsh underground environment, the maintenance work may be relatively complicated and time-consuming. Therefore, when using inspection robots for monitoring, it is necessary to fully consider its performance and applicability to ensure reliable and efficient state monitoring of belt conveyors while reducing production costs and maintenance difficulties. After a comprehensive comparison of various monitoring methods, it may be necessary to select an appropriate monitoring method based on the actual situation to optimize the operation and maintenance management of the belt conveyor and improve the efficiency and safety of the entire coal mine production system.

The most direct parameter changes of roller and frame failures are changes in vibration, temperature and other data. The traditional manual inspection method is inefficient, poor in real-time performance, and has a large number of potential safety hazards. This mode needs to be changed urgently. The distance of the belt conveyor is

long and the number of idlers is large. If conventional point sensors are used for monitoring, the number of sensors that need to be arranged is huge, which is not suitable for on-site monitoring. In addition, inspection robots are expensive to maintain and cannot be monitored continuously, making it difficult to be widely used. None of these methods can achieve full-coverage continuous status real-time monitoring, low efficiency and low practicability, and require regular inspections by technical personnel, which increases personnel safety risks. In order to improve the reliability and stability of the belt conveyor, it is necessary to develop more advanced condition monitoring technology. Such technology can automatically collect data, monitor equipment status in real time, and provide early warning of potential failures, so as to take early measures to avoid possible production interruptions and losses. Continuous improvement and adoption of new monitoring methods will help to optimize the operation of belt conveyors and improve the efficiency and safety of the entire coal mine production system. Research on intelligent, unmanned continuous, real-time online condition monitoring system is the main trend of current development [5].

4. Status Detection of Belt Conveyor Based on Optical Fiber

Optical fiber sensors based on optical fiber technology rely on changes in characteristic parameters such as phase, amplitude, and wavelength of light waves inside the optical fiber, and use mathematical models to analyze changes in external parameters such as vibration and temperature. They have the advantages of anti-electromagnetic interference, small size, high sensitivity, long transmission distance, easy networking, and intrinsic safety. Optical fiber sensing technology is divided into optical fiber grating sensing technology and distributed optical fiber sensing technology [6]. Among them, distributed optical fiber sensing technology can monitor the temperature, strain, vibration and other information of the entire optical cable, realize long-distance status monitoring, and provide a new direction for solving the status monitoring problem of belt conveyors [7]. The comparison of four different monitoring methods is shown in Table 1:

Table 1 Advantages and disadvantages of different monitoring methods

Monitoring Method	Advantages	Disadvantages	Application Recommendations
Manual Inspection	Experienced,technicians can perform regular checks	Requires a large amount of manpower and expertise	Suitable for small-scale conveyor systems
Sensor-based Monitoring	Easy installation,Accurate monitoring parameters	Requires intrinsic safety sensors in underground mines,Battery-powered sensors require regular maintenance,	Widely used in medium and small-scale conveyor systems
Inspection Robot	Unmanned and intelligent, reducing human intervention, Enables autonomous inspections	Unable to achieve continuous monitoring, Complex mechanical and electrical structure,Susceptible to tunnel terrain limitations,	Suitable for complex tunnels and large-scale conveyor systems
Fiber Optic Fault Diagnosis	High sensitivity and wide bandwidth, Enables continuous monitoring, Provides accurate fault information	Still in the research stage,Requires further validation and improvement, May involve some technical challenges	Holds great potential, can be considered for advanced automation coal mining systems

Distributed fiber optic sensing technology omits the need to use multiple sensors in long-distance and distributed infrastructure, where the fiber optic cable itself acts as a continuous sensor capable of measuring multiple parameters such as temperature, strain, and sound, reducing labor costs while realizing distributed state monitoring, In the past decade, researchers have focused on developing DAS-based belt conveyor condition monitoring systems. DAS is a technology that utilizes Rayleigh Back Scattering (RBS) in optical fiber to locate and restore mechanical vibration information (amplitude, phase and frequency) at any position on the optical fiber link, and is one of the potential solutions to provide real-time vibration or acoustic state monitoring of mining belt conveyors [8]. The DAS structure is shown in figure 1.

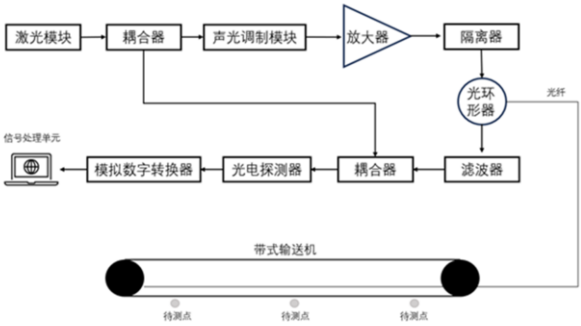
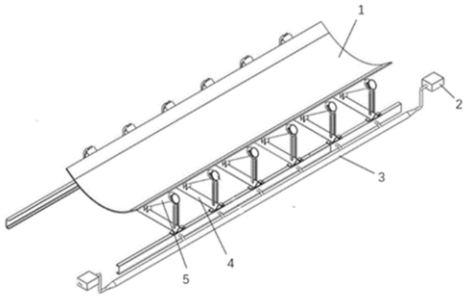


Figure 1 DAS system structure diagram

Because mechanical vibration can usually propagate very far in the medium, DAS can detect events far away from the optical fiber; the low-loss characteristics of the optical fiber allow the monitoring length of the sensing system to reach hundreds of kilometers, so the detection coverage of the DAS system is very wide; the vibration detection bandwidth of DAS can be as high as tens of kilohertz, which can contain rich information about the event to be measured; the sensing optical cable has the characteristics of intrinsic safety, anti-electromagnetic interference, and resistance to harsh environments, which makes DAS have unique advantages in the condition monitoring of mine belt conveyors [9]. The distributed vibration sensing system can be mounted on the conveyor frame with a support structure as shown in figure 2.



1-Belt 2-Optical fiber demodulator 3-Optical fiber 4-Roller stand 5-Roller

Figure 2. Schematic diagram of optical cable installation

5. Conclusions

As one of the main equipment for coal mine transportation, the belt conveyor is prone to various failures due to its special working characteristics, which will cause greater production losses. Therefore, the fault detection of the belt conveyor is particularly important. By introducing the main faults of belt conveyors and their causes, this paper discusses the existing fault monitoring methods of belt conveyors at home and abroad, and analyzes their respective advantages and disadvantages one by one. Finally, an optical fiber-based fault diagnosis method for belt conveyors is introduced.

In general, this paper deeply discusses the main faults of belt conveyors and their causes, and conducts a comprehensive analysis of the existing fault monitoring methods at home and abroad. By introducing an optical fiber-based fault diagnosis method, it provides useful enlightenment for improving the stability, reliability and safety of belt conveyors. In future research, the application of optical fiber sensing technology in belt conveyor fault monitoring can be further explored. At the same time, combined with other intelligent monitoring methods, a more comprehensive and efficient fault early warning and maintenance management system can be formed to provide strong support for the sustainable and stable development of coal mine production.

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