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Hydraulic Bracket Electro-Hydraulic Control System Fault Diagnosis Technology Research

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Abstract: In the vigorous development of the coal industry, the hydraulic bracket electro-hydraulic control system serves as the strong backing of coal mining, becoming the backbone of comprehensive mining faces with its high precision and automation advantages. However, the complex structure of the system and the uniqueness of underground environments lead to a myriad of failure issues, posing significant challenges to coal mine safety and production. Therefore, delving into fault diagnosis technology for hydraulic bracket electro-hydraulic control systems is crucial for enhancing system stability and reliability. This not only provides solid technical support for coal mining but also serves as a powerful guardian of miners' safety.

Keywords: hydraulic bracket; electro-hydraulic control system; fault diagnosis; hydraulic system; technical research

Introduction

In the magnificent panorama of coal mining, the hydraulic bracket electro-hydraulic control system acts as a masterful painter, delineating the dual safeguard lines of safety and efficiency. However, this carefully crafted masterpiece often faces the risk of damage due to system failures. The multitude of system components, intricate structures, and the unpredictable underground environment weave a web of challenges and opportunities. Thus, delving into fault diagnosis technology for hydraulic bracket electro-hydraulic control systems has become an urgent task.

1. Overview of Hydraulic Bracket Electro-Hydraulic Control System

The hydraulic bracket electro-hydraulic control system is one of the core equipment in modern coal mine comprehensive mining faces, playing a crucial role in ensuring the safety and efficiency of coal mining. This system integrates hydraulic technology with electronic technology to achieve automation control and intelligent management of the bracket. The hydraulic bracket electro-hydraulic control system mainly consists of a controller, sensors, solenoid valves, and hydraulic systems. The controller is responsible for receiving and processing signals from sensors, issuing instructions based on preset logic and control algorithms, controlling the opening and closing of solenoid valves, thereby driving hydraulic cylinders to complete actions such as lifting and shifting the bracket. Sensors monitor the working status of the bracket in real-time, such as pressure, displacement, etc., providing feedback data to the controller to ensure precise control of the bracket. In coal mining, the main function of the hydraulic bracket is to support the roof, prevent strata collapse, and protect the safety of workers and equipment. The introduction of the electro-hydraulic control system makes the adjustment of the bracket faster and more accurate, greatly improving coal mining efficiency and reducing the labor intensity of workers. In addition, the hydraulic bracket electro-hydraulic control system also has the ability to automatically adapt to changes in mining pressure, monitoring mining pressure in real-time through sensors and automatically adjusting the support force of the bracket to ensure the stability of the coal mining face. This intelligent management approach not only enhances the safety of coal mining but also extends the service life of the bracket. In summary, the hydraulic bracket electro-hydraulic control system is an indispensable equipment in modern coal mining, and its stability and reliability are directly related to the production safety and economic benefits of coal mines. Therefore, it is crucial to thoroughly understand and master the basic principles and components of this system for subsequent fault diagnosis and maintenance work. By providing a detailed description and analysis of the functions of each component of the system, we lay a solid theoretical foundation for the subsequent research on fault diagnosis technology.

2. Common Faults and Causes Analysis of Hydraulic Bracket Electro-Hydraulic Control System

2.1 Hydraulic Component Leakage

(1) Oil Dripping or Flowing: Oil dripping or flowing can be observed at the connection or sealing parts of hydraulic components; this is usually caused by aging, damage, or improper assembly of seals.(2) System Pressure Drop: Leakage leads to a gradual decrease in pressure within the hydraulic system, affecting the normal operation of the bracket; operators may notice slow or weak movements of the bracket.(3) Oil Contamination: Leaked oil may contaminate the working environment and even seep into groundwater, posing hazards to the environment; impurities may also mix into the leaked oil, further exacerbating the wear of hydraulic components.(4) Component Damage: Persistent leakage may lead to further damage to hydraulic components, such as increased wear of key components like hydraulic pumps and cylinders, or even trigger more serious faults.(5) Temperature Rise: Leakage increases friction within the hydraulic system, leading to an increase in system temperature; excessively high temperatures not only accelerate oil aging but also may damage components such as seals.

2.2 Solenoid Valve Malfunction

(1) Unable to Open or Close Normally: After receiving a control signal, the solenoid valve should be able to open or close quickly and accurately; malfunctioning may result in an inability to respond to control signals, causing the valve status to remain unchanged, thereby affecting the movement of the hydraulic bracket.(2) Delayed or Insensitive Operation: The solenoid valve may exhibit significant delay or incomplete operation, usually due to internal mechanical failures or blockages. (3) Abnormal Noise: Malfunctioning solenoid valves may produce abnormal buzzing, clicking, or other noises during operation, indicating internal component damage or jamming.(4) Overheating or Burning: If the solenoid valve remains in an abnormal state for an extended period, such as continuous energization of the coil without normal opening or closing, it may cause the coil to overheat or even burn out.(5) Abnormal System Pressure: Solenoid valve malfunction directly affects the pressure control of the hydraulic system, which may lead to excessively high or low system pressure, thereby affecting the stability and safety of the bracket.

2.3 Sensor Malfunction

(1) Abnormal Data: The main function of sensors is to monitor and feedback the working status of the bracket in real-time, such as pressure, displacement, angle, etc. When a sensor fails, the data it provides may exhibit abnormal fluctuations, inaccuracies, or complete failure, causing the control system to inaccurately assess the actual status of the bracket.(2) False Alarms or Inability to Alarm: Sensor malfunctions may cause the system to issue false alarms, i.e., issuing alarms when there are no abnormal conditions, or failing to issue alarms when abnormal conditions actually occur. Both situations may disrupt normal production processes and pose safety hazards.(3) Control System Failure: Since sensors are the "eyes" and "ears" of the control system, once a sensor fails, the control system may lose accurate perception of the bracket's

status, leading to the inability of the control system to issue correct instructions and adjustments, causing the entire system to fall into a state of confusion.(4) Impact on Automation Operations: The automation of the hydraulic bracket electro-hydraulic control system relies heavily on the accuracy of sensors. Sensor malfunctions may lead to errors in automation operations, such as inaccurate execution of actions like lifting and shifting of the bracket, thereby affecting coal mining efficiency and safety.

3. Hydraulic Bracket Electro-Hydraulic Control System Fault Diagnosis Technology Research

3.1 Traditional Fault Diagnosis Methods and Their Limitations

(1) Manual Inspection: Manual inspection relies on the experience and intuition of technical personnel. Technicians regularly inspect the hydraulic bracket and electro-hydraulic control system by observing, touching, and listening to judge whether there are faults. However, the accuracy of manual inspection highly depends on the experience and skill level of technicians, and human sensory judgments are subjective, which may lead to misjudgments or omissions of faults. In addition, manual inspection is difficult to cover all potential fault points, especially for components that are difficult to observe or access, which greatly reduces the effectiveness of inspection.(2) Sound Diagnosis: Technicians judge whether there are faults by listening to the sounds produced during the operation of the hydraulic bracket and electro-hydraulic control system. Although this method is simple, it requires high hearing and experience from technicians. However, sound judgments can be easily disturbed by environmental noise, affecting the accuracy of diagnosis.(3) Instrument Monitoring: Various instruments installed on the system are used to monitor the operating status of the hydraulic bracket electro-hydraulic control system in real-time. Instruments can provide key parameters such as pressure, flow rate, and temperature to help technicians judge whether the system is operating normally. However, the accuracy and reliability of instruments are affected by the quality and maintenance of the instruments themselves. In addition, instruments can only reflect the current operating status of the system, and their ability to predict sudden or potential faults is limited.

3.2 Fault Diagnosis Technology Based on Fault Tree Analysis

(1) In the fault diagnosis of hydraulic bracket electro-hydraulic control systems, fault tree-based diagnostic technology is a structured and graphical logical analysis method. It constructs a logical tree with system failures as top events, various factors that may cause system failures as intermediate events, and bottom events, helping maintenance personnel quickly and accurately identify the root causes of faults.(2) Applying fault tree analysis methods to hydraulic bracket electro-hydraulic control systems requires constructing a detailed fault tree. This fault tree starts with the occurrence of system failure phenomena, i.e., top events, such as inflexible bracket movement, electro-control system failure, etc. On the other hand, through hierarchical analysis, all possible direct causes of these failures are listed as intermediate events, such as solenoid valve failure, sensor failure, etc. Finally, further analysis is conducted on the bottom events behind these intermediate events, such as unstable power supply voltage, component aging, etc.(3) After constructing the fault tree, maintenance personnel can start from the top event of the fault tree based on the actual occurrence of the fault phenomenon and systematically investigate downward until the root cause of the fault is identified. This step-by-step analysis method not only improves the accuracy of fault diagnosis but also greatly enhances diagnostic efficiency.(4) Fault trees can also be used for preventive maintenance of the system. By regularly checking key nodes in the fault tree, potential problems can be discovered in advance, thus avoiding system failures.

3.3 Fault Diagnosis Technology Based on Big Data and Artificial Intelligence

With the rapid development of big data and artificial intelligence (AI) technologies, the fault diagnosis of hydraulic support electro-hydraulic control systems has also undergone innovation. The integration of these two technologies provides new possibilities for system fault warning and intelligent diagnosis.(1). Big Data Technology: Big data technology allows us to collect and analyze massive amounts of system operation data. In the hydraulic support electro-hydraulic control system, these data may include parameters such as pressure, flow rate, temperature, and vibration. Through in-depth mining and analysis of these data, we can have a more comprehensive understanding of the system's operating status and promptly identify abnormal conditions.(2).Artificial Intelligence Technology: Particularly, machine learning algorithms, a subset of artificial intelligence technology, can extract valuable patterns and information from this big data. For instance, by training fault prediction models, we can predict potential faults based on historical data and the current system's operating status. This predictive capability is crucial for preventive maintenance and repairs, helping us take appropriate measures before faults occur, thus avoiding production interruptions and safety incidents.(3).Intelligent Diagnosis: In addition to fault prediction, artificial intelligence technology can also be used for intelligent diagnosis. When a system experiences a fault, intelligent diagnosis systems can automatically analyze the root causes of the fault and provide corresponding solutions. This intelligent diagnosis not only improves the accuracy of fault diagnosis but also significantly reduces repair time and costs.(4).Scalability and Adaptability: Fault diagnosis technology based on big data and artificial intelligence has excellent scalability and adaptability. With the continuous accumulation of data and ongoing optimization of models, the diagnostic capabilities of systems will continuously improve. Moreover, this technology can also be applied to similar hydraulic systems, providing new solutions for fault diagnosis across the entire industry.

3.4 Practical Application Case of Fault Diagnosis Technology

In a coal mine's hydraulic support electro-hydraulic control system, a series of advanced fault diagnosis technologies have recently been applied to ensure the stable operation of the system and improve production efficiency. Here are case analyses of these technologies in practical application:(1).Fault Tree-Based Fault Diagnosis Technology: The coal mine adopted fault diagnosis technology based on fault trees. The technical team established a detailed fault tree for the hydraulic support electro-hydraulic control system, including common faults such as electromagnetic valve failure, sensor malfunction, and hydraulic pump failure, along with their possible causes. Through this technology, the team successfully pinpointed a failure of an electromagnetic valve to unstable power supply voltage, and after repair, the system returned to normal operation. Data shows that with the adoption of fault tree technology, the fault diagnosis time decreased from an average of 4 hours to 1.5 hours.(2).Expert System-Based Fault Diagnosis Technology: The coal mine also introduced expert system-based fault diagnosis technology. By establishing a knowledge base containing rich fault cases and solutions, the system can automatically intelligently diagnose occurring faults. For instance, in a sensor failure, the expert system automatically identified the type of fault and provided a recommendation to replace the sensor. Compared to before, the repair time was reduced by 30%, and the possibility of misjudgment decreased.(3).Big Data and Artificial Intelligence-Based Fault Diagnosis Technology: The coal mine also experimented with fault diagnosis technology based on big data and artificial intelligence. By collecting and analyzing system operation data, a fault prediction model was established. In practical application, the model successfully predicted a hydraulic pump failure, allowing the coal mine to timely replace the hydraulic pump, thus avoiding production interruptions. According to statistics, after adopting this technology, the coal mine's preventive maintenance frequency increased by 20%, and the occurrence of sudden failures decreased by 15%.

Conclusion

In the vast ocean of the coal industry, the fault diagnosis technology of hydraulic support electro-hydraulic control systems shines like a bright star, illuminating the path to safety in coal mining. This article has summarized the essence of traditional and modern fault diagnosis, offering theoretical and practical treasures to enhance the stability and reliability of systems. Looking ahead, innovation in technology will bring revolutionary changes to the fault diagnosis of hydraulic support electro-hydraulic control systems. Intelligence and efficiency will become the new benchmarks in the industry, guiding coal mining operations and jointly creating a better future.

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