Overview of the faults and diagnosis methods of the hydraulic system of modern coal mining machines

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\textbf{Abstract:} The high power, high efficiency, low failure rate, and intelligence of coal mining equipment are important directions for the development of coal mining machines both domestically and internationally. The implementation of efficient and low failure coal mine equipment is an important prerequisite for ensuring the smooth deployment of intelligent mines. At present, coal mining equipment generally consists of three parts: mechanical, electrical, and hydraulic. However, hydraulic pressure is a necessary system for coal mining equipment to complete high-power and intelligent operations. This article will combine the author's years of work experience to summarize the current local faults and diagnostic methods of hydraulic systems in coal mine equipment.

\section{1. Basic characteristics of hydraulic system of coal machine}

The hydraulic system of the coal machine (hereinafter referred to as the "hydraulic system") is a mechanical equipment from the analysis of the main body of the coal machine, which is closely related to mechanical technology. Because the hydraulic system's own fluid properties are different from the mechanical structure, its working principle, working medium and structural process characteristics are different from the other two types of coal machine systems \cite{1}. The hydraulic system has its own unique transmission mode, control mode and application mode. In the process of transforming coal mining equipment from highly mechanized to intelligent, the existing high-power, low-automatic hydraulic system setting technology can no longer meet the requirements. Therefore, part of the hydraulic system has completed the mutual information exchange and energy exchange with the electronic computer system. The current mainstream development direction of coal mining equipment is unmanned intelligence and remote operation. Therefore, it is necessary to realize the complete monitoring of all hydraulic systems of coal mining machinery and make corresponding fault diagnosis, and to give a reasonable maintenance plan is a necessary process for the current coal mining machinery discovery \cite{3}. This article hopes to realize the intelligentization of coal machine hydraulic system as soon as possible, and will explain some common coal machine hydraulic system faults and diagnosis methods below.

\section{2. Overview of the faults of the hydraulic system of the coal machine and the fault characteristics}

\subsection{2.1. Overview of the failure of the coal machine hydraulic system}

The failure of the hydraulic system is generally caused by the failure of the hydraulic components or hydraulic medium to reach the expected functional level, which causes the whole machine to not work normally. The failure of the hydraulic system of the coal machine is usually accompanied by vibration, noise, and high temperature \cite{4}. However, most of these phenomena are caused by the inability of hydraulic equipment and external conditions to meet the requirements of normal operation. In most cases, the faults of the coal machine hydraulic system can be roughly divided into the following 6 attributes.

1) The faulty component is the component that has failed. Hydraulic components are the basic unit that constitutes hydraulic equipment. When the hydraulic components fail, the overall performance of the hydraulic equipment will decrease or fail. Therefore, only an in-depth and systematic understanding of the principle, structure, function, and failure mechanism of hydraulic components can successfully analyze field failures and even eliminate them.

2) Fault parameters, that is, physical quantities that characterize the loss of or appearing function of the hydraulic device. Such as pressure, flow, leakage, speed, torque, action sequence, position, efficiency, vibration, noise, and oil port,
vacuum, etc. When the above parameters exceed the design maximum value range, it means that the hydraulic system is malfunctioning.

3) Failure phenomenon, that is, when the key parameters of the hydraulic system are abnormal, the hydraulic system failure can be observed artificially. Such as obvious abnormal equipment noise, system weakness and high temperature.

4) Fault information, that is, characteristic information that reflects the internal damage of the hydraulic device. The fault phenomenon is only part of the fault information. Equipment alarm signals, system test analysis conclusions, equipment service life and operation records are also fault information. The fault information and the fault have a certain corresponding relationship, which is the starting point and basis for judging the fault.

5) The cause of the failure, that is, the initial cause of the failure. Mainly include oil pollution, mechanical wear and fracture failure, design and manufacturing problems, installation problems, inconsistent changes in link conditions, and human factors.

6) The scope of the fault, and the content of the fault design. Some failures are single, and some are comprehensive. The former is caused by an abnormality of individual factors, while the latter involves multiple links. For example, when the hydraulic oil is contaminated, it will cause more spool stuck in the hydraulic system, and the electromagnetic will burn out.

2.2 Fault characteristics of coal machine hydraulic system

Because the working environment of coal mining machinery is worse than that of ground equipment, the fault investigation, fault diagnosis and fault resolution of the coal machine hydraulic system have the following characteristics.

1) Concealment The damage and failure of hydraulic devices often occur in the deep interior. Due to the inconvenience of assembly and disassembly, the detection conditions on the site are limited and it is difficult to observe directly. In addition, the surface fault phenomenon of the hydraulic system is more difficult to obtain, such as the internal holes of the hydraulic main control valve of the continuous miner. Once collusion and blockage occur, the overall action of the continuous miner is out of adjustment, but the difficulty coefficient of the entire valve body to accurately determine the fault is too large.

For example, the schematic diagram of the hydraulic system of a coal machine is shown in Figure 1. The fault is that the working pressure is about 41 MPa, and the unloading pressure is only about 1 MPa lower than the working pressure. When the system runs for 10 minutes, the oil temperature of the hydraulic system rises above 50°C. After an on-site inspection, it was found that the main oil circuit and the relief valve unloading control oil circuit that caused this problem were abnormally colluding on the valve plate. In the figure below, the collusion oil circuit is indicated by a dashed line. When the hydraulic pump circulates through the main oil circuit, a small part of the hydraulic oil will flow through the reversing valve through the orifice connected by the dotted line and then return to the hydraulic oil tank. The reversing valve has a small diameter and resistance, so the pressure of the hydraulic oil before the reversing valve is P1. This pressure makes the relief valve under the secondary pressure control, the relief valve spool cannot be fully opened, and the system pressure rises. The oil is heated by the throttle valve. At that time, the technicians did a detailed inspection of the hydraulic system components of the vehicle in the mine, and found no suspicious points. Finally, all components were subjected to a pressure test during the equipment overhaul, and it was found that the main overflow valve plate was caused by liquid leakage.
2) Staggeredness There are various overlaps and crossovers between symptoms and causes of hydraulic system failures. A symptom may have many causes. If the speed of the actuator is slow, the causes may include excessive load, wear of the actuator itself, excessive guide rail error, leakage in the system, pressure regulating system failure, speed regulating system failure, pump failure, etc. A certain symptom may be caused by a combination of multiple reasons. For example, when the pump, reversing valve, and hydraulic cylinder are all in a worn state, the efficiency of the system is greatly reduced. When these parts are replaced one by one, the efficiency of the system will also increase. For comprehensive faults, the influencing factors should be fully considered, and the priority should be resolved one by one.

3) Randomness During the operation of the coal machine hydraulic system, it is affected by a variety of random factors, such as changes in underground voltage, changes in ambient temperature, and changes in the geology of machine excavated rock tunnels. The intrusion of pulverized coal during the mining process is also random. Due to the influence of random factors, the direction of the specific change of the fault is not certain, which will aggravate the difficulty of judgment and quantitative analysis.

4) Differences Due to differences in design, processing materials, and application environments, the wear and deterioration speed of hydraulic components varies greatly. General hydraulic component life standards cannot be applied in the field. Specific wear evaluation standards can only be determined for specific hydraulic equipment and hydraulic components. However, this process requires long-term operation data accumulation.

3. Diagnostic method for key parameters of hydraulic system of coal mining machine

The main work content of hydraulic fault diagnosis includes.

3.1 Formula calculation method

Some of the current hydraulic system parameters cannot be directly obtained and need to be obtained through mathematical models, as shown in the following formula:

\[ q_v = \frac{v_f \cdot \eta_0}{1000 \cdot \eta_v} \]

\[ n = \frac{q_v \cdot 1000 \cdot \eta_v}{v_f} \]

flow: \( q_v \) unit: L/min

displacement: \( v_f \) unit: cm³

Revolution: \( n \) unit: rpm

Volumetric efficiency: \( \eta_v \)

3.2 Key parameter lookup table

For some key parameters that can be directly obtained or calculated through the 3.1 formula, they can be compared with the calibration values, and the comparison accuracy is shown in Table 1 below.

<table>
<thead>
<tr>
<th>Measurement parameters</th>
<th>Measurement accuracy level</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure (gauge pressure &lt; 0.2MPa) KPa</td>
<td>±1.0</td>
<td>±3.0</td>
<td>±5.0</td>
<td></td>
</tr>
<tr>
<td>Pressure (gauge pressure &lt; 0.2MPa) (%)</td>
<td>±0.5</td>
<td>±1.5</td>
<td>±2.5</td>
<td></td>
</tr>
<tr>
<td>flow (%)</td>
<td>±0.5</td>
<td>±1.5</td>
<td>±2.5</td>
<td></td>
</tr>
<tr>
<td>torque (%)</td>
<td>±0.5</td>
<td>±1.0</td>
<td>±2.0</td>
<td></td>
</tr>
<tr>
<td>temperature (%)</td>
<td>±0.5</td>
<td>±1.0</td>
<td>±2.0</td>
<td></td>
</tr>
</tbody>
</table>

3.3 Simulation analysis comparison

For some key parameters that are difficult to directly measure in new hydraulic systems, simulation can be used to input measurable parameters and obtain other key explanations for fault analysis. The key parameter simulation of a certain system is shown in Figure 2.
4. Conclusion

According to the current development trend of hydraulic system fault diagnosis technology both domestically and internationally, the hydraulic system fault detection methods currently being studied and preliminarily applied internationally include vibration diagnosis method, acoustic vibration method, thermodynamic diagnosis method, material optical analysis method, neural network\(^5\), etc. However, the widely used methods mentioned above include formula calculation, table lookup, and model simulation and analysis. These widely used methods will have significant development and application in the future when combined with new technologies under research.

References