Overheat fault analysis of drillship electric winch drive system

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Abstract—In order to solve the problem of winch motor overheating, this paper analyzes the possible reasons of motor overheating along with the structure and principle of drillship winch. Taking the overheating fault of drillship's driving motor as the top event, the fault tree model of the overheating problem of the driving motor is established, and the relative weak links of the winch are found out through the minimum cut set. With the result of fault tree analysis as a guide, the lifting device was inspected, the fault reason of the lifting device was found out, and the corresponding solutions were put forward. The results show that the proposed method in the paper can improve the efficiency of fault location.

1. INTRODUCTION
With the rapid development of offshore oil and gas resources development technology in recent years, offshore oil and gas has gradually become an important source of energy [1]. Drillships have been widely used in offshore oil and gas exploration and development due to the good mobility, high cost performance and high efficiency [2]. As an important equipment in drilling engineering, winch is usually employed in lifting and dropping operations during offshore oil and gas developing. The winch drive system is the critical component of the winch. The performance of the drive motor have a significant impact on the life and operation reliability of the winch system. In this paper, the fault tree model of the overheating of the driving motor is established and the fault position located quickly with the fault tree analysis method.

2. Introduction to drillship winch system
2.1. Structure and Working Principle of Winch System
The drillship winch is composed of four parts, including driving motor, gear box, brake device and control system [3-6]. The winch system is as shown in figure 1. When the winch system
Fig.1 The winch system

running, PLC gives control instruction to the main control center (MCC) and make the driving motor to
positive and negative rotate. Then, the drum is driven after the speed reduced though the gear box and
the object is lifted up or dropped down.

2.2. Drive Motor Structure
The drive motor is the most malfunction equipment in the drillship winch mechanical system. The type
of the drive motor is MCC652 three-phase asynchronous motor. The basic parameters are shown in
Table 1. F20 electro-magnetic brake is used in this motor, when the lifting system stops working, the
electromagnetic coil of the electromagnetic brake is not energized, and the brake disc is closely attached
to the brake armature under the force of the spring, so the motor is braked. In order to ensure the
reliability of the work, the gap between the brake disc and the armature is usually within the range of
0.5mm-2mm.

Table 1 Basic parameters of three-phase asynchronous motor

| Parameter   | Specification | Parameter   | Specification |
|-------------|---------------|-------------|---------------|
| Frequency   | 50Hz          | Type        | MCC652        |
| Vol         | 600V          | Insulation grade | H           |
| Power       | 355KW         | environment temperature | 50°C          |
| speed       | 1800rpm       | Protection level | IP56         |
| current     | 577A          | Weight      | 1000Kg        |

3. Overheat Fault Analysis of Drive Motor

3.1. Fault Tree Modeling of Motor Overheating
In order to solve the overheating fault of the drillship, the motor overheating fault tree model is establish
with the fault tree analysis method and the model is as shown in Figure 2. In this model, the overheating
fault of the driving motor is as the top event and the mechanical fault, winding fault, brake fault and
bearing fault are as the basic event. The list of events is shown in Table 2, in which the driving motor
overheating T is the top event, and the internal motor fault E1, external motor fault E2, and poor heat
dissipation E3 are the intermediate events.
3.2. The Minimum Cut set of the Fault Tree

Minimum cut set is a fault mode in the fault tree that causes the top event occurrence. Through the analysis of the minimum cut set, the potential weak links of the system can be found and the improvement measure can be used to optimize the system design. The number of the minimum cut set has an important influence on the reliability of the system. With the fault tree method, the expressions of the top event and the middle event are found, and the minimum cut set of the fault tree is obtained. The minimum cut set is as shown in Equation (1).

\[
G_6 = X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} + X_{12}
\] (1)

After analyzing the fault tree of the driving motor overheating, 12 minimum cut sets are found and the minimum cut set leading to internal failure of the drive motor is the most [7-8]. Therefore, the internal structure of the driving motor should be checked firstly when inspecting the motor overheating fault, and then the external load and power supply of the driving motor should be checked.

4. Overheat fault check of drive motor

4.1. Motor overheating fault description

In engineering application, the phenomenon of abnormal overheating of the driving motor of the winch in the process of lifting and lowering appears. When lifting 12 meters, the motor suddenly appeared high temperature phenomenon, the temperature rose from 27°C to 88°C. After continuing the hoisting operation, the monitoring data showed temperatures of up to 182°C and burnt marks on the motor brake.
4.2. *Field fault diagnosis*

In view of the possible causes of overheating of the motor and the fault phenomenon of the motor, the observation hole of the motor brake disc is opened to detect the motor brake device. It is found that the armature is reliable in the process of falling by the point-moving test operation system. The brake disc and brake armature are in a moderate position, and the gap between them is within a reliable working range. The motor overheating problem is not caused by the adjustment of the installation clearance of the brake device.

The structure of the gear reduction box is shown in Figure 3. Further check other structures of the drive motor and the structure of the gear reduction box. It is found that the parallelism error between the input shaft axis and the intermediate shaft axis of the gear reduction box is too large, which causes the meshing error of the gear pair to be too large. In the process of platform descent, due to the large meshing error of gear pair, the input shaft of gear reduction box and the main shaft of driving motor always bear large axial push component force. The main shaft of the motor pushes the brake disc to shift towards the armature direction under the action of the axial component force, which causes the passive friction between the brake disc and the armature and generates a lot of heat, which leads to the increase of the motor load and the occurrence of overheating fault.

![Fig.3 Gear reduction box structure](image)

5. *Solving Measures of Winch Device*

After disassembly detection, it was found that the concentricity error between the input shaft and the middle shaft at both ends of the gear reducer was as high as 0.15mm, which exceeded the allowable error range. After the gear box and the shell are fixed, the shaft sleeve holes at both ends of the input shaft and the intermediate shaft were repositioned and processed. The measured results shown that concentricity meet the requirements. Then the bearing sleeve was installed by liquid nitrogen cooling, and the gear box is reassembled after the cleaning. The winch system was in good running condition and high temperature phenomenon did not appears during the 1-hour test running. The overheating problem of the driving motor has been solved perfectly.

6. *CONCLUSION*

In this paper, the fault tree method is used to analyze the overheating fault of the drillship winch, and the minimum cut set of the fault tree is built and used to identify the fault reason. The results show that internal failure of the drive motor is the primary reason and the method provided in the paper improves the efficiency and correctness of winch fault diagnosis.

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