Fault Diagnosis and Predictive Maintenance Technology of Ship Power System

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Abstract: The purpose of this paper is to discuss the research progress and application practice of fault diagnosis and predictive maintenance technology for marine power system. In view of the challenges faced by the safety and reliability of the power system in the current shipbuilding industry, this paper puts forward a variety of fault diagnosis and predictive maintenance methods in order to build an efficient, intelligent and reliable fault diagnosis and maintenance system. In terms of methods, through comparative analysis and case study, this paper expounds in detail the fault diagnosis technology based on signal processing, knowledge reasoning, model analysis and the predictive maintenance technology based on data-driven and physical models. At the same time, according to the advantages and disadvantages of these methods and the scope of application, a multi-level system architecture including data acquisition, processing, fault diagnosis, performance prediction and maintenance decision support is designed. By monitoring all kinds of operation data of ship power system in real time, the system can accurately identify fault types and locations, predict the performance degradation trend of the system, and provide timely decision support for maintenance personnel, thus improving the safety, reliability and economy of ship power system.

1. Introduction

With the continuous development of global trade, ships, as an important means of logistics and transportation, play a decisive role in the marine economy [1]. Ship power system is the heart of the ship, and its stable and efficient operation is directly related to the safety and economic benefits of the ship [2]. However, due to the complex and changeable operating environment of the ship, the power system is under the condition of high load and high vibration for a long time, which is prone to various faults and brings great risks to the ship operation [3]. Therefore, it is of great significance to study the fault diagnosis and predictive maintenance technology of ship power system for improving the safety, reliability and economy of ship operation.

In addition, with the progress of science and technology, especially the rapid development of information technology, artificial intelligence and other fields, it provides new methods and means for fault diagnosis and predictive maintenance of ship power system [4]. By introducing advanced diagnosis technology and prediction algorithm, the fault of power system can be found in time, accurately located and effectively prevented, thus reducing maintenance costs, reducing downtime and improving the overall operational efficiency of the ship [5].

2. Marine power system foundation

2.1. Composition and working principle of power system

Ship power system refers to the system that provides propulsion and other required energy for the ship [6]. It usually consists of main engine, auxiliary engine, transmission device, propeller and related control systems and auxiliary equipment (as shown in Table 1).

The performance of ship power system directly affects the speed, maneuverability, economy and safety of the ship [7]. Therefore, in the process of ship design and operation, it is necessary to comprehensively consider and optimize the power system to ensure that it meets the needs of the ship under various working conditions.

The working principle of marine power system can be simply summarized as follows: the engine burns fuel to produce high temperature and high pressure gas, which pushes the piston to move and

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drives the crankshaft to rotate; The crankshaft transmits power to the propeller through the transmission device; The propeller uses the received power to generate thrust and push the ship forward. In this process, various auxiliary systems and equipment are needed to ensure the normal operation of the power system, such as cooling system, lubrication system, fuel system and exhaust system.

Table 1 Composition and function description of ship power system

Component	Describe	Function
Main engine	The core of power system	Provide the power needed for ship navigation.
Auxiliary engine	Including cooling system, lubrication system, power supply system, etc.	Provide necessary auxiliary services for the mainframe and other equipment, such as cooling, lubrication, power supply, etc.
Transmission device	Including shafting, gearbox, clutch, etc.	Transfer the power of the main engine to the propeller to push the ship forward.
Propeller	Such as propeller, water jet propeller, etc.	Use the power transmitted by the transmission device to generate thrust and make the ship sail.
Control systems	Including monitoring instruments, regulating devices, automatic control systems, etc.	Monitor and adjust the power system to ensure its stable and efficient operation.

2.2. Common failure types and their causes

The ship's power system may encounter a variety of faults during operation, which will not only affect the normal navigation of the ship, but also pose a threat to the safety of the ship [8]. Common fault types and their causes are as follows:

(1) Engine failure: The engine is the core component of the power system, and its failure types are various, including difficult starting, insufficient power and unstable operation. The causes of these failures may be fuel system blockage, ignition system failure, cylinder wear and so on.

(2) Transmission device failure: The transmission device is responsible for transmitting the power of the engine to the propeller, and its common failures include gear wear, bearing damage and bending of the transmission shaft. The causes of these failures may be long-term high-load operation, poor lubrication, installation errors and so on.

(3) Propeller failure: Propeller is a component that generates thrust, and its common failures include blade wear, cavitation corrosion, shafting vibration, etc. The causes of these failures may be water erosion, water corrosion, improper installation, etc. In addition, the propeller may be hit by foreign objects or improperly operated during navigation, which may also lead to failures.

In addition to the above three common faults, the marine power system may encounter other types of faults, such as control system faults and cooling system faults. The causes of these failures may be equipment aging, short circuit, pipeline leakage and so on. In order to ensure the normal operation of the ship's power system, it is necessary to maintain and inspect all kinds of equipment and systems regularly to find and eliminate potential safety hazards in time.

3. Fault diagnosis technology

3.1. Classification of fault diagnosis methods

Fault diagnosis technology is an important means of maintenance and management of marine power system, which can detect and identify faults in the system in time and accurately, and provide decision support for maintenance personnel [9]. According to the application principle and technical characteristics, fault diagnosis methods can be divided into the following categories:

(1) Method based on signal processing: This method collects the signal of the ship power system, and uses signal processing technology to extract the characteristic information in the signal, so as to judge whether there is a fault in the system. The advantage of this method is real-time, but it requires high signal quality and processing algorithm.

(2) Knowledge-based method: This kind of method makes use of the known fault information

and diagnosis experience to diagnose the fault of the ship power system by constructing knowledge bases such as expert system, fuzzy logic and neural network. It is suitable for dealing with complex and uncertain fault problems, but it needs to constantly update and improve the knowledge base.

(3) Model-based method: This method establishes the mathematical model of the ship power system, and uses the residual between the model and the actual system to detect and isolate faults. It can accurately reflect the dynamic characteristics of the system, but it requires high accuracy and real-time performance of the model.

(4) Data-driven fault diagnosis method: This method uses machine learning, data mining and other technologies to analyze and learn a large number of historical data of ship power system, extract fault features and establish a fault pattern recognition model. It doesn't need accurate modeling of the system, but it needs enough data to support it.

3.2. Fault diagnosis application case

Taking the fault diagnosis method based on signal processing as an example, it is assumed that the engine in the ship power system has abnormal vibration. Maintenance personnel can use the acceleration sensor to collect the vibration signal of the engine, and then extract the frequency components from the signal through spectrum analysis technology. By comparing with the frequency components in normal state, we can find the changing law of frequency components in abnormal vibration, so as to judge whether there is a fault in the engine and the type and location of the fault. This method has a wide application prospect in real-time fault diagnosis of ship power system.

4. Predictive maintenance technology

4.1. Concept and method of predictive maintenance

Predictive maintenance technology is a maintenance strategy based on data-driven or physical model, which can predict the performance degradation trend of ship power system, make maintenance plans in advance, avoid unexpected downtime or reduce maintenance costs. Predictive maintenance methods mainly include the following:

(1) Prediction method based on time series: Using the time series information in the historical data of ship power system, the future state of the system is predicted by establishing a time series model. It can reflect the long-term trend and seasonal change of the system, but it needs to smooth the data and select the model parameters.

(2) Prediction method based on machine learning: The performance degradation trend of ship power system is studied and predicted by using machine learning algorithm. It can automatically extract the feature information from data and establish a complex nonlinear relationship model, but it needs a lot of historical data for training and optimization.

(3) Prediction method based on physical model: By establishing the physical model of ship power system, the performance degradation trend of the system is simulated and predicted by using the model. It can accurately reflect the physical characteristics and dynamic behavior of the system, but it needs accurate modeling and parameter identification of the system.

4.2. Forecast maintenance application prospect

With the continuous development of sensor technology, data processing technology and artificial intelligence technology, the application prospect of predictive maintenance technology in ship power system is more and more broad. It can realize the following functions: predict the performance degradation trend and remaining life of ship power system in advance, and provide decision support for making reasonable maintenance plan; Real-time monitoring of the operating state and abnormal situation of the ship's power system, and timely finding and handling potential safety hazards; Optimize the operation parameters and maintenance strategy of ship power system to improve the operation efficiency and reliability of the system. In the future, predictive maintenance technology will be deeply integrated with fault diagnosis technology, remote

monitoring technology and cloud computing technology to jointly promote the intelligent and green development of marine power system.

5. System design and practice

5.1. System design objectives and architecture

Under the background of fault diagnosis and predictive maintenance technology of marine power system, the main goal of system design is to build an efficient, reliable and intelligent diagnosis and maintenance system. The system should have real-time monitoring, fault diagnosis, performance prediction, maintenance decision support and other functions to ensure the safe, stable and economical operation of the ship's power system.

To achieve the above objectives, the architecture of the system design can be divided into several levels as shown in Figure 1:

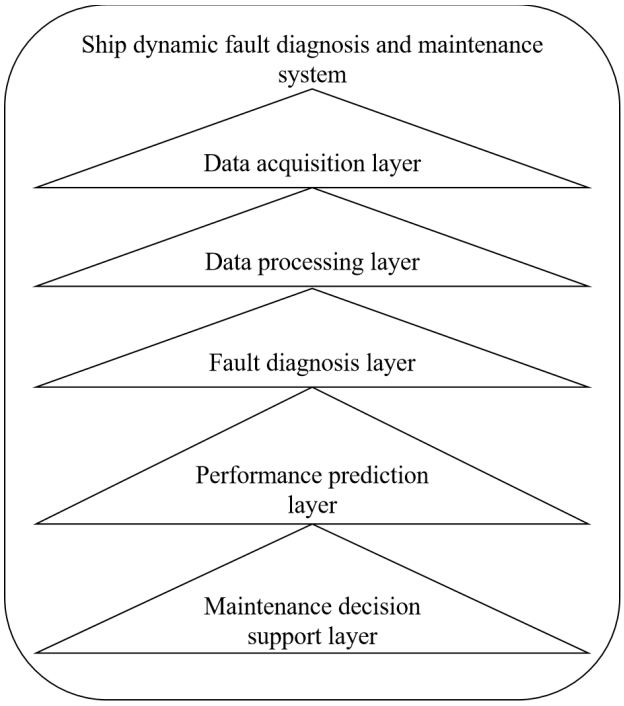

Figure 1 The architecture of ship dynamic fault diagnosis and maintenance system

Data acquisition layer: it is responsible for collecting all kinds of operation data of ship power system in real time, such as temperature, pressure, vibration, speed, etc., and providing data support for subsequent fault diagnosis and performance prediction. This layer needs to interface with various sensors and actuators of the ship power system to ensure the accuracy and real-time performance of the data.

Data processing layer: preprocess the collected original data, such as denoising, filtering, normalization, etc., to extract useful feature information. At the same time, this layer also needs to store and manage data to facilitate subsequent analysis and query.

Fault diagnosis layer: the fault diagnosis algorithm is used to analyze and judge the processed data and identify the possible faults in the ship power system, their types and positions. This layer needs to design a variety of fault diagnosis methods to adapt to different types of faults and different operating conditions.

Performance prediction layer: based on historical data and current operation state, the performance degradation trend of ship power system is predicted by using prediction algorithm, and the remaining life and possible failure modes of the system are estimated. This layer needs to select a suitable prediction model and train and optimize the model to improve the prediction accuracy and real-time performance.

Maintenance decision support layer: according to the results of fault diagnosis and performance

prediction, formulate corresponding maintenance strategies and optimization suggestions to provide decision support for maintenance personnel. This layer needs to comprehensively consider the safety, economy, reliability and other factors of the ship's power system in order to achieve the best maintenance effect.

5.2. Practical application case analysis

Taking the power system of a certain ship as an example, this paper introduces the practical application of fault diagnosis and predictive maintenance system. The system has successfully realized the functions of real-time monitoring, fault diagnosis and performance prediction of ship power system in actual operation. By collecting all kinds of operation data of the ship's power system and analyzing and judging the data by using the fault diagnosis algorithm, the system can accurately identify the fault type and location, and send an alarm in time to remind the maintenance personnel to deal with it. At the same time, the system can also predict the performance degradation trend of ship power system according to historical data and current operation state, and provide decision support for making reasonable maintenance plan. After practical application, the system has achieved remarkable results in improving the safety, reliability and economy of ship power system.

6. Conclusions

In this paper, the fault diagnosis and predictive maintenance technology of ship power system is studied. Through combing and analyzing the existing technologies, the fault diagnosis technology based on signal processing, knowledge reasoning, model analysis and predictive maintenance technology based on data-driven and physical models are put forward. On this basis, an efficient, reliable and intelligent fault diagnosis and maintenance system architecture is designed, and the effectiveness and practicability of the system are verified by practical application cases. The main contributions of this paper include:

(1) The research status and development trend of fault diagnosis and predictive maintenance technology of marine power system are systematically sorted out, which provides reference for subsequent research;

(2) A variety of fault diagnosis and predictive maintenance methods are proposed, and their advantages and disadvantages and application scope are analyzed;

(3) A complete fault diagnosis and maintenance system architecture is designed, which realizes real-time monitoring, fault diagnosis, performance prediction, maintenance decision support and other functions.

(4) The effectiveness and practicability of the system are verified by practical application cases, which provides a strong guarantee for the safe, stable and economic operation of the ship power system.

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