Research on torsional vibration monitoring system of ship power shafting

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Abstract. In this paper, the real-time monitoring technology of ship power system torsional vibration is studied. The photoelectric non-contact measurement method is used to measure the torsional vibration intensity of shafting, and the analysis service network management platform is established to realize the functions of real-time monitoring of shafting torsional vibration and upload and collect alarm data, through the front-end system, the torsional vibration strength and other parameters of the shafting are collected and transmitted to the background. The data of the background system is used to calculate and analyze, and the status of the shafting is alarmed. The system realizes continuous monitoring and data recording of torsional vibration index of ship power system, and ensures the operation performance and safe operation of ship power system. It provides theoretical and technical support for the future development of new technologies and related research, such as durability simulation and durability virtual test of ship power critical parts.

Keywords: Power shafting, Torsional vibration, Monitoring system, Sensor.

1. Introduction
Marine propulsion shafting is an important part of a marine power plant, which is mainly composed of power plant, transmission shaft and propeller[1]. The transmission shaft is used to transmit the power from the power plant to the propeller to make it rotate and generate propulsion. The torsional vibration of shafting is one of the important factors affecting the reliability of marine power plants. Severe torsional vibration will cause excessive alternating stress in shafting, resulting in deformation and fatigue failure of shafting, and even torsion fracture[2]. In recent years, frequent shaft breaking accidents have sounded an alarm for us. In order to improve the safety of ships in all aspects, we should pay special attention to the torsional vibration of ship propulsion shafting[3]. Therefore, this paper studies the real-time monitoring technology of ship power system torsional vibration, develops a set of ship power shafting torsional vibration monitoring system, realizes the continuous monitoring and data recording of ship power system torsional vibration index, and ensures the operation performance and safe operation of the ship power system.

2. System composition and signal acquisition

2.1. System Composition
The real-time monitoring system of shafting torsional vibration is a comprehensive system with the functions of real-time data acquisition and processing, analysis, alarm, record storage, print output and so on. It includes the front-end data acquisition and preprocessing system, including the measurement and analysis system of shafting torsional vibration stress and shaft power, shafting vibration measurement and analysis system, shafting energy efficiency monitoring and feedback system, transmission system and back-end processing system. The overall block diagram is shown in Figure 1.

2.2. Signal Acquisition

As shown in the figure, the measurement and analysis of ship power shafting torsional vibration mainly adopts photoelectric non-contact measurement method to measure the torsional vibration strength of shafting. The vibration signal of shafting is collected by sensors, and the amplitude of shafting vibration is judged in the monitoring and early warning unit through preprocessing technology. According to the preset alarm parameters, combined with intelligent comprehensive judgment, adaptive correction technology, fault feature model prediction, fast Fourier transform (FFT), cloud computing intelligent upgrade and other technologies, the monitoring and early warning of shafting vibration is carried out.

Figure 1. Detection system of marine power shafting.

2.3. Torsional Angle Threshold and Actual Measured Value

Figure 2. Torsional vibration signal acquisition.
The torsional vibration monitoring system (the first generation) of marine power shafting is a tool used to continuously monitor the torsional angle of power shafting. When the amplitude reaches or exceeds the safety limit, the system will send out an alarm signal. At the same time, the system can display the engine speed, operation time and so on. The amplitude obtained by measuring torsion angle can be output to PC for result analysis. As shown in the figure, the actual measured torsion angle of 70 turns, the actual measured torsion angle of 60 turns and the torsion angle threshold are respectively. It can be seen from the threshold chart that the threshold values corresponding to the torsional vibration speed of 60 and 70 revolutions are 23 and 22 respectively. In the actual measured torsional angle values, the peak value of torsional angle at 60 revolutions is about 16, and the peak value of torsional angle at 70 revolutions is about 12, which do not exceed the corresponding threshold values. It can be concluded that the vessel is in normal operation.

**Figure 3.** Torsional angle threshold and actual measured value.
3. Design of Shafting Torsional Vibration Online Monitoring System

Development of algorithm model research and embedded software of rotor vibration monitoring and fault alarm prediction analysis system: in the monitoring, alarm and early warning unit, development of various application module components based on different algorithm models, running in high-performance embedded processor system under the control of embedded real-time operating system (RTOS), and its technical architecture is shown in Figure 4. The data acquisition of torsional vibration, rotational speed, shock absorber oil temperature and pressure are carried out by the sensor module. After preprocessing the collected data, real-time data analysis, fault prediction characteristic analysis and adaptive data analysis based on cloud service after data storage can be carried out.

On the one hand, the real-time data analysis can go through the time domain amplitude calculation module and frequency domain characteristic analysis module. The analysis results can be displayed and queried in real time, and the working state of the shafting can also be comprehensively judged by the time-frequency analysis results. According to the appearance time and frequency-domain threshold data comparison, the safety alarm or limit alarm can be given, and the occurrence time of various alarms in the system can be monitored, duration and overrun data are stored and analyzed.

On the other hand, the fault prediction characteristic analysis module filters and processes the real-time monitoring data and alarm records according to the pre-stored parameters and algorithms, and gives fault warning according to the processing results. The adaptive data analysis module adjusts the alarm threshold data in time domain and frequency domain appropriately through the long period analysis of the measured historical data and the preset adaptive algorithm. In addition, the data upgrade module from the cloud can collect and upload the measured data and alarm data of the ship on the one hand, and update the fault early warning model and adaptive data analysis model upgraded by cloud computing on the other hand. The cloud service module can also update the time domain threshold data and frequency domain threshold data. The comprehensive judgment module gives the alarm signal intelligently through the preset strategy model judgment.

Figure 4. Technical framework of torsional vibration monitoring system.

4. Demonstration of Ship Shafting Torsional Vibration Monitoring System

4.1. Design of Calculation and Analysis Service Platform for Monitoring System

The calculation and analysis program uses the big data obtained from the real-time torsional vibration monitoring of multiple ships to analyze and process the data including the real-time torsional vibration monitoring data of multiple ship types, alarm record data, torsional vibration fault data, etc. Through
various analysis programs constructed by the server, extracts the data features, establishes the torsional vibration feature database, and establishes various analysis models, the model algorithm is extracted and an embedded software package is generated to upgrade the shafting torsional vibration monitoring system.

![Block diagram of system calculation and analysis service platform](image)

Figure 5. Block diagram of system calculation and analysis service platform.

The network management platform of calculation and analysis service as shown in Figure 5 is established to provide upload, management and upgrade service systems for all shafting torsional vibration monitoring systems of the whole ship system. Based on the above-mentioned big data analysis and processing, the system realizes various processing and analysis functions, including real-time torsional vibration monitoring and alarm data upload and collection; Statistical analysis of monitoring data characteristics combined with ship type classification; Comprehensive statistical analysis of alarm record characteristics of different ship types; Real time monitoring data and fault characteristics extraction and analysis of shafting fault ship; The structure and parameters of adaptive model algorithm are improved and modified; The improvement and modification of algorithm structure and parameters of shafting fault prediction model; Fault prediction and early warning analysis based on real-time monitoring data comparison of the same ship type.

4.2. Function Demonstration of Monitoring System

The monitoring host is usually placed in the engine control panel in the engine control room. All cable connections are located at the rear of the monitoring host, which is composed of a touch screen and printed circuit board with a microprocessor. It has the function of calculating the phase speed of rotating elements.
Figure 6. Torsional vibration monitoring system of ship power shafting.

The specific monitoring interface is shown in the figure below, as shown in Figure a, the main interface shows the trend of torsional vibration of the current relevant parameters of the monitored components. As shown in Figure b, the signal interface displays the real-time measured values of the relevant parameters of the torsion angle of the power shaft in one cycle, including the real-time amplitude of the rotation angle in one cycle. As shown in Figure c, the curve interface shows the specific power shaft torsion angle limit curve of the monitored component. Color: Orange: warning limit curve; Red: alarm limit curve. As shown in Figure d, the alert log display includes two parts: the current active alert and the logged alert. As shown in Figure e, the system check interface displays the information of the monitor system itself. As shown in Figure f is the warning recording interface, the system sends the alarm signal to AMS of the ship, and AMS makes a prompt or alarm sound to inform the operator. After the operator confirms the event, the monitoring system stops transmitting the alarm information, and AMS stops responding. The operator can also check all active alarms on the alarms page.
5. Conclusions

In this paper, the technical research of ship power shafting torsional vibration monitoring system meets the requirements of multi working conditions, dual channel synchronous online monitoring of ship power shafting torsional vibration, and plays an important role in ensuring the main engine operation performance and safe operation of the ship:

(1) Compared with the regular monitoring of shafting torsional vibration characteristics in the past, the marine power shafting torsional vibration monitor can complete the continuous monitoring of the indicators and obtain the first-hand real-time data, so as to analyze the continuous slow change and short-term mutation of shafting characteristics, and grasp the abnormal or fault symptoms of marine propulsion shafting in time, so as to take corresponding measures, timely replacement or repair of failed parts to avoid or reduce the occurrence of major accidents.

(2) The fault prediction function of the torsional vibration monitor is the biggest characteristic of the instrument which is different from the previous torsional vibration tester. Based on a large number amount of continuous accumulated data, the multi-party early warning calculation model is designed to improve the accuracy of fault diagnosis of monitoring systems.

(3) Once a fault occurs in the propulsion shafting of a ship, the monitoring system can automatically record the complete data and information of the fault process, so as to diagnose and analyze the fault causes afterwards and avoid the occurrence of similar faults again; Through the analysis of the causes and properties of the abnormal state of ship propulsion system, the change of its operation state, the deterioration degree and development trend of the performance of main parts and subsystems are mastered, and the normal operation time is predicted, which provides the basis for the scientific decision-making of equipment maintenance time and mode.

References

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