Research Article
Research on Acquisition and Communication Technology of Marine Equipment Fault Diagnosis Information for Vessels in Inland Rivers

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Abstract: This study describes a system for the analysis of the fault diagnosis of marine equipments in inland rivers. Since the normal operation of the marine equipments significantly influences the ship safety, this study develops an efficient fault diagnosis information system for the condition monitoring and fault diagnosis of marine equipments. In this new system, field bus and ship-to-shore communication technologies have been integrated for the fault diagnosis information acquisition. Then the application of network bus, including CAN and RS485, has been employed to connect the fault diagnosis information with Ethernet in the ship. Lastly, for the real time and wireless transmission of the fault information, the Automatic Identification System (AIS) technology has been adopted to provide accurate and reliable fault diagnosis information transmission from ships to onshore diagnosis center. A comprehensive study of the application of proposed fault diagnosis information system has been implemented for remote diagnosis of marine equipments. The analysis results demonstrate that the newly developed fault diagnosis information system can enhance the fault diagnosis precision and hence is competent for the condition monitoring and fault diagnosis of marine equipments in inland rivers.

Keywords: AIS, fault diagnosis, field bus, ship-shore technology, vessels

INTRODUCTION

The trouble shooting of the equipment installed in geographically distant locations brings the remote diagnosis technology, which would achieve savings in cost and time for both customers and manufacturers. The vessels in inland rivers work in an environment of complexity and uncertainty, with the lack of technical support, so the marine equipment condition monitoring and remote fault diagnosis would significantly improve the reliability of the marine equipment (Wang *et al.*, 2004; Ramnath *et al.*, 2011).

However, both the fault mechanism and system circumstance of marine equipments are of great complexity. Therefore, there are various types of information, leading to complex structure and coupling effect of the information system. Great progress has been made in this field (Ramnath *et al.*, 2011). Nevertheless, it is rather difficult to monitor the marine equipment comprehensively, as the integrated data usually produce a relatively correct diagnosis result. Besides, the communication among relevant departments on ship, or between ships and shore would promote the marine equipment monitor information service; a hysteretic information communication system may lead the miss of the best opportunity for fault prevention. The research on acquisition and communication technology of marine equipment fault diagnosis information for vessels in inland rivers is accordingly imperative, which would be of great significance of the vessel safety. This study examines the measure of the integration of field bus and AIS technology which would overcome the difficulties found in previous study.

SYSTEM STRUCTURE

Equipment fault diagnosis technology is combined with field bus technology, computer network technology and communication technology. Under normal circumstances, a condition monitoring server computer is equipped on board and by setting many condition monitoring points on important marine equipments, the real-time condition monitoring data would be sent to the fault diagnose server. The fault identification and primary diagnosis are then acquired. On the other hand, the fault diagnosis centre is set onshore, which would get access to the fault monitor data and the primary diagnosis results via ship-shore communication. Therefore the onshore centre would provide remote technical support to ships.
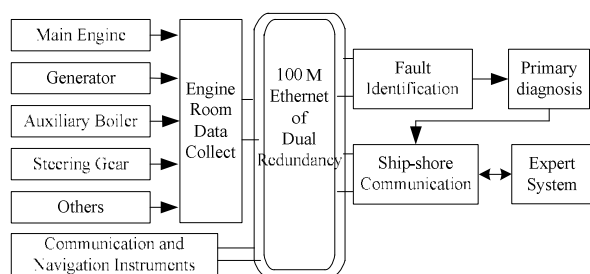
Fig. 1: The system structure

Fig. 2: The information acquisition system

The acquisition and communication system of marine equipment fault diagnosis information for vessels in inland rivers, based on the intelligent and network platform, would include both the field acquisition and ship-shore communication sub system. The system structure is shown in Fig. 1.

In Fig. 1, the data from marine equipments, including main engine, generator, auxiliary boiler and so on, are collected via proper field bus and connected to a couple of Ethernet of dual redundancy with communication interfaces; the ship-shore communication technology is the integration of communication technology, computer and network technology, which would connect the service centers onshore and vessels remotely, thus the personnel on shore could provide technology support by monitoring and analyzing the information of marine equipments, with which the safety maintenance and fault diagnosis of the marine equipments for inland rivers ships is possible. In this study, we shall first introduce the information acquisition field bus and it will be followed by a description of the development of Ship-shore communication system based on AIS.

Information acquisition field bus for fault diagnosis:
The engine room involves the most equipment on board including main engine, generators, auxiliary boiler, air conditioner, hydraulic system, water generator, steering gear, oil separator and so on. The type of equipment fault diagnosis information is varied with the monitoring methods. Taking power equipments for example, there are three kinds of methods for fault diagnosis, they are oil monitoring, vibration analysis and parameter analysis and each method involves the corresponding analysis of various physical quantities to be collected, judged, processed and displayed.

With the development of marine technology, a variety of relatively independent automated systems, equipped in navigation system, propulsion system, power system and auxiliary system, have been developed, but each subsystem is developed respectively for a specific purpose and various data interfaces or methods are formed, within which the
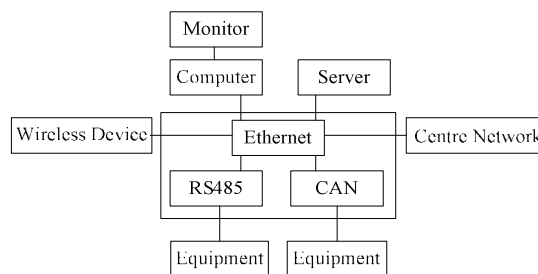
CAN (Controller Area Network) bus and RS485 bus are most widely used. So both of the CAN bus and RS485 bus are selected for the fault diagnostic information collection of the marine equipments of inland ships.

The acquisition and communication system is constructed with the following considers:

- The severe environment for marine equipments including strong electromagnetic interference
- The low compatibility of different communication type
- The flexibility, expansibility, stability of the Ethernet

Based on the above points, an information acquisition field bus for fault diagnosis is developed, which is shown in Fig. 2. After the field data of the equipments are acquired by CAN and RS485, the information is sent to Ethernet with the adoption of Winsock technology and UDP protocol, subsequently the Ethernet is connected to the centre network and then wireless devices, industrial computer and server, so the real-time monitor of the marine equipments is realized.

CAN bus: CAN bus is a serial multi-master controller area network bus composed of CAN controller. Because of its advantages like multi hosts, long transmission distance, high transmission speed, high communication speed, perfect reliability and strong anti-interference and so on, the CAN bus has already become one of the most popular field bus and the above advantages make it particularly suitable for interconnection of small and medium-scale industrial process control equipments, transport vehicles electrical system.

CAN protocol is based on the international standards organization's open systems interconnection model. In September 1991, Philips Semiconductors formulated and published the CAN technical regulation. There are two modes in current version: standard mode and extended mode (Cavalieri *et al.*, 1996).
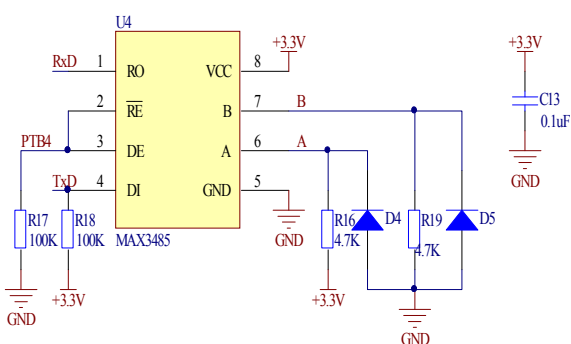
Fig. 3: The circuit of RS485

Fig. 4: The reference model of ethernet protocol interface of diagnostic information

While the local information of fault diagnosis is acquired for ship equipments in inland rivers, it can be encoded by a particular form to transmit multi-channel data at the same time, thus improving the efficiency of the transmission of information or data. When the multi-channel data are inserted simultaneously, CAN bus protocol layer classifies them according to the priority classification, transfers them by sorting different priorities to avoid the multiple data confliction. Diagnosis information of equipments fault should take the advantage of the CRC test, which improves the accuracy of the diagnostic. It is significant for strong electromagnetic interference and strong vibration interference of the actual environment in the engine room.

RS485 bus: The RS485 bus for fault diagnosis information of inland rivers ships is essentially a physical layer standard, the data frame format is defined by the user, including the address information.

RS485 bus network technology is quite mature with a simple structure, high reliability, high communication speed, good anti-interference ability. It is currently used in many electrical devices. RS-485 bus realizes its communication by sending in a balanced way and receiving in a differential way. The good anti-interference and confidentiality of the data could ensure the instantaneity and reliability of the data transmission, another advantage of RS485 is to collect the fault information from more than one device of engine room simultaneously (Liu, 2005).

The change of TTL level to differential signals is realized by using MAX3485. The 485 communication circuit is shown in Fig. 3. The system does not require adding RL ending resistors in most cases. Only when the transmission range is more than 300 m, end resistors need to be added at the head and the end of 485 communications.

Ethernet interface bus: Ethernet was developed in the 1970 s as a baseband local area network technology, with the adoption of carrier multi-access bus structure,
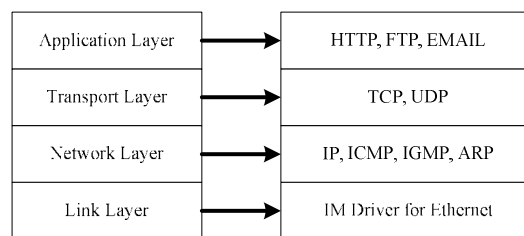
it follows the CSMS/CD media access control approach, the data exchange in packets, Ethernet belongs to the physical layer and data link layer in 50/051 structure. Its features are: simple structure, low cost, good compatibility, good expandability, high stability and strong maintainability. It has been widely used and become the most common communication protocol standards in the existing local network, with a wide range of applications in the real environment of equipments fault diagnosis of inland rivers ships.

In the real environment of engine fault diagnosis of inland rivers ships, the fault information for different devices usually adopts different communication protocols, which brings inconvenience of the collected information communication and this is not appropriate for the subsequent development of equipment and capabilities expansion. The adoption of Ethernet interface bus in the fault diagnosis would solve this by multi-protocol conversion in data transmission process of different communication protocols, the broadcast of the diagnostic information collected through the TCP/IP protocol to LAN would facilitate the long-range wireless transmission.

The reference model of Ethernet protocol interface for diagnostic information is divided into the following four layers: application layer, transport layer, network layer and data link layer. They are logically independent and each layer consists of a number of sub-protocols, shown in Fig. 4 (James and Keith, 2009; Li, 2010).

The network of ship borne diagnosis information based on field bus would improve the ability of mutual collaboration and the diagnosis efficiency. The automatically monitoring solutions of engine room in this study can not only monitor various parameters circularly, it also realize multi-source data fusion by running the device in the network and initial diagnosis, the information display through the man-machine interface and the Ethernet-based communication protocol provides technical support to achieve ship-shore data communication.
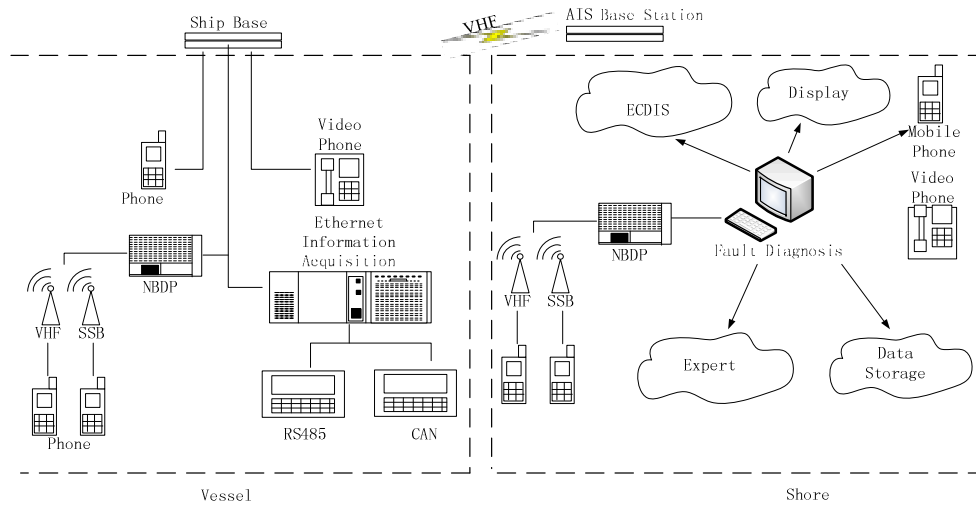
Fig. 5: The ship-shore data transmission system

SHIP-SHORE COMMUNICATION

Because of the particularity of the inland rivers ship, ship-shore communication is always the focus of the shipping community. High expenditure and the low stability of the traditional communication made the ship to be "information isolated island".

The transmission of the fault diagnosis information of inland rivers ship is not merely deal with the fault treatment, but also the failure prevention. The occurrence of any failure of the marine equipment would accompany with the corresponding warning, which can reflect subtle changes in certain parameters. It is expected that by analyzing the marine equipment operating parameters, the engineers could take appropriate measures before a failure occurs and reduce or even avoid the cabin equipment failure. So the establishment of an automated communication highway between ship and shore is expected, in order to make the ship management tends to the high number of integration, automation, which can step on to a new level and make contribute to the safe navigation of ships and ship remote fault diagnosis.

There are two main kinds of communications methods for ship-shore communication at present. The first category includes AIS, SSB (NDBP), VHF and so on; the other one is Marine Satellite communications equipment, including Inmarsat-A, B, C, M, F and so on. Considering the characteristics of inland navigation vessel and the data volume of operating parameters of engine room equipment (Wu *et al.*, 2008), the cost of maritime satellite communication is too high, so it is not appropriate for the ship-shore information data transfer of fault diagnosis information. After a
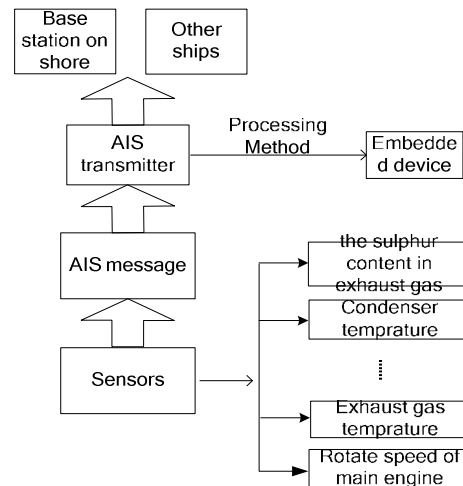

Fig. 6: The AIS information sending flow

comprehensive comparison of several currently existing forms of ship-shore method, AIS is selected as the ship-shore communication method, which is important for the ship's real-time performance monitoring and site maintenance of cabin equipment, the Ship-Shore data transmission system based on AIS is shown in Fig. 5.

AIS works on VHF marine band, it is a data transmission system between ships or ships and shore bases, a growing number of ships have equipped with AIS and it is considered as a supplement to radar. The AIS information collection and exchange function on base station improves and strengthens the vessel traffic service management functions of VTS.

The maritime administration can receive information automatically sent by shipboard AIS. AIS applied secret code to send information following the

Table 1: The definition of message 6

Parameter	Bytes	Explanation		
Message identification code	6	Message 6's identifier		
Forward indicator	2	Used to display the times of resend messages; 0~3; default = 0; 3 = should not to resend		
Message sources indicator	30	Message source's MMSI		
Serial number	2	0~3		
Objective station's indicator	30	Objective station's MMSI		
Resend sign	1	Set the sign if it is resend message; 0 = not resend; 1 = resend		
Reserve	1	Not use, set 0		
Binary data	936	Application ID codes	16 bits	NULL or international ID codes
		Application data	920 bits at most	Specific application data
Total bits	1008	According subfield message length, take 1~5 time slots		

Table 2: The definition of message 8

Parameter	Bytes	Explanation		
Message identification code	6	Message 6's identifier; always 8		
Forward indicator	2	Used to display the times of resend messages; 0~3; default = 0		
Message sources indicator	30	Message source's MMSI		
Reserve	1	Unused, set 0		
Binary data	936	Application ID codes	16 bits	NULL or international ID codes
		Application data	920 bits at most	Specific application data
Total bits	1008	According to subfield message length, take 1~5 time slots		

communication mechanisms. AIS information can be applied after collecting, decoding, classifying and processing, during the whole process, AIS is an information collector. It classifies and saves the processed information to Intranet server database (Yang, 2006). Figure 6 is the AIS terminal information sending flow chart by the example of main engine.

Equipments fault information parameters are added into the AIS message, then it is broadcasted to shore base and passing ships. By this way, Message 6 and Message 8 can be selected as information channel. The definition of Message 6 and 8 are shown in Table 1 and 2. As shown in the two tables, both Message 6 and Message 8 can send message larger than 900 bits, which fully meets the requirements of the inland rivers ships' engine fault information transmission. Both the two messages are custom protocols. As they transmit binary data, it can express parameter values which need to be transmit in binary and transmit in binary.

However AIS technology has its own limitations to transfer marine equipments fault information, bandwidth of AIS channel is as narrow as 25 k and the transmission of picture and video becomes difficult, thereby affecting the reliability and stability of the fault diagnosis.

According to the present mature communication technology, GPRS and 3G transmission technology can be applied as the supplement in the inland rivers ships fault diagnosis information transmission.

The application of GPRS technologies may provide short text messages and support the standard RS232 interface information output. GPRS module transfers the fault diagnosis information parameters to a server IP, this technology effectively overcomes the disadvantages of the radio environments and electromagnetic interference and it is more favorable for long-range wireless data transmission.

While in some situation, the fault diagnosis information can hardly be expressed by data or text, remote video transmission by 3G technology can be considered. Through 3G wireless video transmission, the dynamic state of the engine equipment can be transferred remotely in real time, so the technical personnel on the shore can clearly understand the equipment's running state and can effectively guide the crew for troubleshooting and equipment maintenance (Ding, 2006).

Therefore, to ensure the reliability and real-time accuracy of fault diagnosis information transmission, the use of AIS technology, GPRS technology and 3G technology could be taken into account. Ship owners and relevant technical staff can realize the fault conditions with a clear aim real-timely and that has great importance for guiding marine officers to deal with engine equipment failure particularly.

CONCLUSION

The computer network and communications technologies have been being developed rapidly, which make it possible for providing professional service in geographically distant locations for the purpose of fault diagnosis. With the help of computer and communication technology, the vessel field bus acquires the fault diagnosis information and the communication is achieved between the shore-based service center, so as to monitor the operation condition of the vessel device and provide technical service. Hence, the fault diagnosis and safety maintenance of the vessel equipments can be realized, which would be of great importance for the vessel to sail safety and reduce the cost.

This study analyses the problem from the angle of system structure, information acquisition field bus and ship to shore communication, the main conclusions include:

- By the fusion of the field bus and ship to shore communication, the acquisition and communication system of marine equipment fault diagnosis information for vessels in inland rivers can be developed, which lays the foundation for the further promote of digital vessel.
- Combined with the characteristics of inland ship, CAN bus and RS 485 bus are designed as on-site terminal acquisition, which have good compatibility and communicativeness to connect fault diagnosis information with Ethernet and send marine engine fault diagnosis information ashore by wireless transmission equipment on board.
- Aiming at the reliability, real time property and accuracy of the fault diagnosis information transmission, by the analysis on varies of ship to shore communication means, the fault diagnosis information transmission system is designed based on AIS technology, with the integration of a variety of ways. Also the related communication protocols based on AIS message is developed.

By the analysis in this study, it can be seen that the acquisition and communication system of marine equipment fault diagnosis information for vessels in inland rivers could solve the previous problems to great extend, reduce the accident rate and promote the benefit. The future work could be developed from:

- The modeling and simulation of the developed system
- Reliability research of the developed system
- Test on ship
- Optimization and enhancement of the developed system

ACKNOWLEDGMENT

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