Application and Exploration of Self-Inspection Methods for Acoustic-Magnetic Control Systems

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Abstract: This paper describes the application of self-inspection methods for a large-scale acoustic control system of "ton" level and two large-scale electromagnetic control systems of "ton" level in the current underwater acoustic-magnetic simulation field industry of ships. Based on the current situation of the usage environment of the three types of control systems, starting from the overall structural block diagrams of the three types of control system equipment, it briefly introduces the generation mechanism of the control systems. By avoiding the practical difficulties in the signal detection methods of the control systems of the three large-scale equipment in engineering applications, the signals of the control systems are selectively closed-loop or segmented. Finally, three conventional and universal application theories of control system signal detection methods are formed. Through practical experience, three specific operation methods and techniques are provided to people, thus forming the application and research results of three acoustic-magnetic control system inspection methods.

Keywords: Acoustic-Magnetic Control Systems; Signal Detection; Methods and Techniques

1. Introduction

1.1 Research Status

Acoustic-magnetic control systems have found extensive applications in a variety of industries, particularly in the crucial fields of underwater detection and underwater weapons. In real-world scenarios, these systems are required to meet specific and often stringent standards regarding acoustic signal intensity and magnetic field width. This necessity leads to the acoustic-magnetic actuating components of the associated equipment being typically characterized by their large physical size and significant weight [1,2]. For instance, in the development of advanced sonar systems for deep-sea exploration or highly precise magnetic detection devices for naval defense applications, the actuating parts need to generate and manipulate strong acoustic and magnetic fields over extended ranges [3].

In China, the engineering approach for large-scale acoustic-magnetic equipment commonly involves a two-step process. Initially, the design of the control and actuating components is carried out separately [4,5]. After the individual design phases, the two components are then integrated and undergo a comprehensive debugging process. During this stage, the combined system is rigorously tested under various simulated and real operating conditions. The judgment of whether the acoustic-magnetic generation is functioning properly and meeting the desired specifications is based solely on the outcome of the system's joint operation [6]. This holistic approach ensures that the entire system, from the control signals generation to the final acoustic-magnetic field emission, works in harmony and achieves the intended performance goals, thereby enhancing the effectiveness and reliability of the equipment in its intended applications.

1.2 Purpose and Significance

At present, the effect judgment of most acoustic-magnetic equipment is based on the overall output of the system work, which is largely limited by the test platform. Building a test platform requires a suitable test site and personnel cooperation. For the control system, it is a waste of manpower and material resources. Therefore, it is necessary to explore an effective method to complete the closed-loop inspection of the acoustic-magnetic control system independently without relying on the system debugging. Considering the difficulty in judging the control effect of the current acoustic-magnetic control system, this paper strives to break away from the limitations of system debugging and explore a new closed-loop inspection method combined with practical applications.

The acoustic-magnetic control systems studied in this paper include three types: α acoustic control system, β electromagnetic control system, and ε electromagnetic control system. The closed-loop inspection signal cutoff position of the α acoustic control system is at the integrated control cabinet; the closed-loop inspection signal cutoff position of the β electromagnetic control system is at the β control cabinet; the cutoff position of the ε electromagnetic control system is at the ε control cabinet.

2. Control Principles of Three Types of Acoustic-Magnetic Control Systems

2.1 Working Principle of α Acoustic Control System

The α acoustic control system consists of a sound generating device, a control device, a towing device and an auxiliary device. The content related to this research is the control device [7]. The sound generating system of the α acoustic control system can be regarded as a random vibration control system, and its control principle is shown in Figure 1.

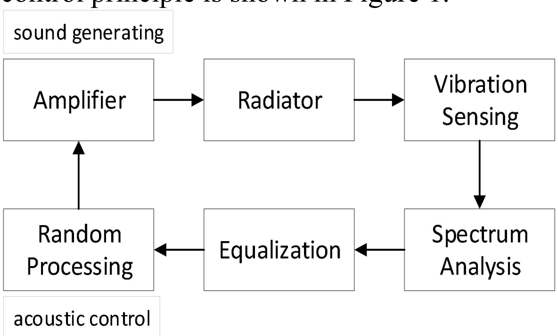

Figure 1. Block Diagram of The Random Vibration Control Principle of the α Acoustic Control System

During operation, the control center console sends the reference spectrum data selected from the data file to the acoustic controller. The acoustic controller first takes the reference spectrum as the driving spectrum, processes it to obtain a time-domain random signal, and then transmits it to the α sound generating device through the communication system after D/A conversion [8]. The power amplifier module in the α sound generating device amplifies the signal and drives the low, medium and high frequency radiators to emit broadband random noise. The acoustic field information radiated by the sensor is amplified and then transmitted back to the acoustic controller through the communication system. After processing, the measurement spectrum is obtained. The measurement spectrum is compared with the reference spectrum and corrected, and then a new driving spectrum is given. This cycle makes the frequency spectrum of the acoustic field radiated by the sound generator consistent with the target acoustic field spectrum, realizing the sound generating function.

2.2 Working Principle of β Electromagnetic Control System

The β electromagnetic system consists of a β execution system and a β control system. The content related to this research is the control system [9]. The β electromagnetic control system is an electromagnetic control system based on the control idea of "setting according to electromagnetic generation" (that is, based on the setting method of an irregular wide-range adjustable magnetic field), and its control block diagram is shown in Figure 2.

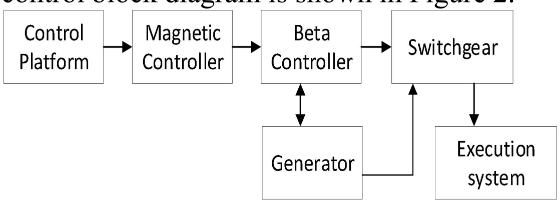

Figure 2. Block Diagram of The Random Vibration Control Principle of the Beta Acoustic Control System

During magnetic field operation, the host of the control center console sends working parameters and start-stop instructions. The CPU of the magnetic controller calculates the waveform control data according to the working parameters and instructions and stores them in the FLASH of the magnetic controller. After the magnetic controller receives the start instruction of the β control cabinet, it reads the control data in the FLASH and periodically repeats DA and IO output. At the same time, the CPU of the magnetic controller collects the magnetic field working condition data of the execution system and automatically and continuously sends them to the host of the control center console for display, so as to monitor the actual effect of magnetic field generation in a timely manner.

The β electromagnetic system has a manual working mode and an automatic working mode. The difference lies in the forced start or automatic closed-loop start of the electromagnetic signal by the β control cabinet. This paper mainly studies the automatic working mode. In the automatic mode, the magnetic controller outputs the loop waveform control signal, the polarity control signal, collects the excitation voltage, the loop current and the ready signal of the β control cabinet to realize the control of the β magnetic field uplink signal.

The β electromagnetic control cabinet is the core control equipment of the β electromagnetic system. Its special feature is that it realizes functions such as driving amplification, overload protection, signal monitoring and feedback processing of control signals. These functions are especially crucial in the automatic working mode.

The principle of the automatic mode is that the automatic module (power module) in the β electromagnetic control cabinet receives the 0 - 20 mA waveform signal and the polarity signal sent by the magnetic controller. After circuit signal processing, it is output to the power amplification module, and then drives the generator set through power amplification, and finally drives the execution system to complete the magnetic field output operation. During the magnetic field output process, the generated current and voltage are on the one hand compared and judged by the protection module and then output to the control center console for uplink monitoring, and on the other hand collected by the sensor and directly displayed on the mechanical test meter of the β electromagnetic control cabinet for local monitoring.

2.3 Working Principle of ε Electromagnetic Control System

The ε electromagnetic system consists of an electromagnetic body, a towing system and a control system. The content related to this research is the control system [10]. The ε electromagnetic system is an electromagnetic system that generates a magnetic field based on the "target setting" method (that is, based on the setting method with controllable magnetic field form and reliable magnetic field data of the sample ship model), and its control block diagram is shown in Figure 3.

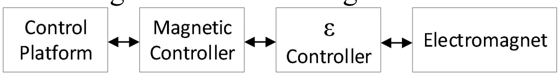

Figure 3. Block Diagram of The Random Vibration Control Principle of the ε Acoustic Control System

During magnetic field operation, the magnetic controller sends n magnetic body target simulation control signals and n polarity control signals through the analog signal output and digital signal output of the CPU according to the instructions and parameters set by the host of the control center console. The programmable controller of the ε control cabinet controls the three-phase auto-transformer and the DC contactor with the full-bridge switch function. Finally, a bipolar constant current or a rectangular wave current with alternating polarity and attenuated amplitude is provided for the electromagnetic body through the towing system, and the output current amplitude is fed back to the control center console for display. The electromagnetic body follows Ampere's solenoid rule and generates a magnetic field change through the current change of the winding group to realize the function conversion.

3. Application of Closed-Loop Inspection Methods for Three Types of Acoustic-Magnetic Control Systems

The closed-loop inspection of the three types of acoustic-magnetic control systems needs to be carried out independently of the actuating components. That is, the idea of the original system joint work should be abandoned and the debugging should be carried out independently. Therefore, in general, the control system signals should be intercepted or the actuating components should be replaced by corresponding sensors.

The α sound generator of the α acoustic control system has a wide frequency band, high intensity and complex structure. At present, it is not possible to make a corresponding analog load to replace the sound generator for closed-loop inspection. Therefore, the closed-loop debugging of the control system is pushed upward to the signal source of the communication system. That is, the acoustic controller is made self-closed-loop to achieve the closed-loop inspection of the acoustic control system

According to the control principle of the α acoustic control system, the closed-loop signal intercepting position for the self-closed-loop inspection of the control system can be selected before the input of the optical transceiver of the acoustic controller, that is, the output terminal of the acoustic controller. The acoustic controller consists of high, medium and low frequency band controllers. Each frequency band controller includes five circuit boards such as a motherboard, a digital-to-analog conversion board, a data processing board and an input-output IO board. The output of the controller is on the IO board.

Through actual measurement and verification, there is a row of debugging terminals on the IO board, with terminal numbers TEST:2 - TEST:13. Among them, TEST6 is connected in parallel with the right low frequency (medium frequency, right high frequency) feedback input of the IO board, TEST10 is connected in parallel with the left low frequency (medium frequency, left high frequency) feedback input of the IO board, and TEST5 is output to the optical transceiver. For self-closed-loop, 5/6/10 can be short-circuited, and the optical transceiver can be unplugged at the same time to intercept the acoustic-5 signal here.

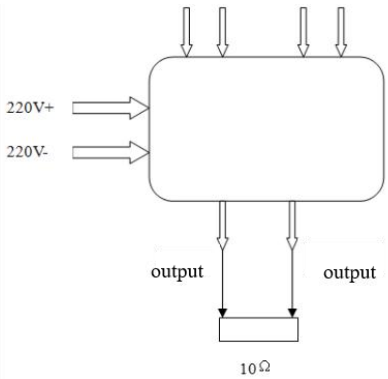

Figure 4. Diagram for Power Module Linearity Inspection

Observe the vibration control spectrum. When the vibration control spectrum is within the tolerance band and the control spectrum is very ideal (the input and output of the IO board are exactly the same), it proves that the control part of the α acoustic control system works normally, that is, the self-closed-loop is completed, as shown in Figure 4.

4. Conclusion

In general, the primary condition for the inspection methods of the three types of acoustic-magnetic control systems is to systematically understand the acoustic-magnetic generating devices, selectively intercept and detect signals, and maximize the closed-loop inspection of the equipment system functions. Whether it is the signal interception method detection of the α acoustic control system and the β electromagnetic control system or the signal detection of the ε electromagnetic control system, either of these two detection ideas can provide a general thinking platform for the future detection methods of electromagnetic control systems.

In today's highly competitive world, the traditional acoustic-magnetic generation mode may not be able to meet the needs and development of society. Workers in the acoustic-magnetic industry need to continuously improve their technical levels, keep up with the pace of the times, base on the current situation, and gradually establish more new acoustic-magnetic control models and put them into practice, striving to become the leaders in the industry.11-point, non-boldface type.

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