Application Research of Eddy Current Testing in Fault Detection of a Ship's SAB Unit

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Abstract. A ship uses four Sabroe 163 units and two Sabroe 128 units as the chiller for the general and special air conditioning systems. After ten years of operation and use, it entered the overhaul. It is planned to determine the damage condition of the heat exchanger tubes of the evaporator and the condenser by eddy current method to determine the next maintenance plan. Due to the ship's docking overhaul, the eddy current flaw detection has been equipped with conditions for draining the equipment, cleaning the heat exchange tubes, purging the inner wall of the heat transfer tubes, and drying. This eddy current testing was performed by a maintenance engineer using a dedicated device that was calibrated.

1. Introduction

When there are certain defects on the metal surface or subsurface that need to be detected, it is necessary to use the eddy current testing technology, which uses the electromagnetic field to complete the detection of the metal surface. In the mid-19th century, electromagnetism began to develop. With the changes of the times, researchers found that when metal and coils with different electrical conductivity were brought into contact, different test results were produced. Subsequently, the researchers proposed eddy current technology, and with the continuous development of this technology, the technology has been widely used in many fields. The essence of this technology is to place a live coil next to the metal sample that needs to be tested for flaw detection, and then there will be induced eddy currents in the sample to be tested. When there are some defects on the metal surface or subsurface compared to normal metal samples, the eddy currents will change. This is because the size and shape of the coil, the frequency and size of the current affect the size and distribution of the eddy current. Not only that, the surface of the metal sample to be tested has defects, the distance between the coil and the metal sample to be tested. Conductivity and the like also have an effect on the size and distribution of the eddy current. Therefore, when other variables remain unchanged, the phase and magnitude of the metal sample to be tested can be estimated by detecting the change of the magnetic field caused by the eddy current change of the coil, thereby clarifying the relevant information of the metal sample to be tested, such as the presence of the surface and the subsurface. Defects, size and shape, texture, conductivity, etc. The technology is easy to use, simple and fast, and usually takes only a few seconds to complete the test, so this technology can be used to test samples on the production line. In addition, the use of this technology does not require prior cleaning of the sample to be tested, nor does it require the use of a couplant. Eddy current testing techniques are related to conductivity, so this technique can be used to detect differences between alloy materials.
In some footnotes of engineering drawings, there is sometimes a sentence: "Explosion using eddy current testing technology"; but it does not clearly indicate which area on the component should be inspected, and it is not pointed out that the purpose of using eddy current testing is what: Finding defects? Verify the heat treatment process? Or thread inspection? Engineers want to use a mature technology to verify the quality of engineering components, but eddy current testing technology can not be used as a test technology, so in order to obtain the correct flaw detection results, fully understand the operation method and application of this flaw detection technology. The scope and principle are necessary.

2. Eddy current detection principle

Among the five conventional non-destructive testing techniques commonly used today, there are electromagnetic eddy current testing. In recent years, with the deep understanding of eddy current technology and the development of computer instrumentation and digital signal processing technology, eddy current non-destructive testing technology has been more widely used. Compared with other non-destructive testing technologies, electromagnetic eddy current testing technology has many advantages, such as detection without contact with the sample to be tested, high sensitivity, and detection in a short period of time. It is more common when testing heat exchanger tubes.

The principle of this technology is electromagnetic induction. A high-frequency alternating current is passed through the excitation coil of the probe, and eddy current is generated in the wall of the tube. If the size of the tube changes, the electromagnetic is abnormal, or there is a geometric defect, the eddy current generated by the tube wall is caused. When the eddy current changes, the induced voltage and impedance of the coil are also affected, and the signal about the defect is obtained. According to the change of the amplitude and phase of the signal, the size and defect of the tube can be obtained.

Copper tube is a relatively common non-ferrous metal and can also be called a copper tube. The material has high strength, good thermal conductivity and light weight, so it can be used for drawing and pressing seamless tubes, so it is often used in the manufacture of heat exchangers such as condensers, and also for cryogenic tubes. Road manufacturing. If the diameter of the copper pipe is small, it is often used for the production of the pressure pipe of the instrument, or for the production of the hydraulic system, the lubrication system, and the like. Flaw detection method and device The eddy current detection method of copper and copper alloy tubes can be divided into three types according to the form of the probe, which are respectively an interpolating coil method, a rotary point probe method and a through coil method. Before the eddy current testing of the copper tube, the sample tube having the same or similar performance index as the detected tube must be prepared in advance, for example, having the same or similar electromagnetic properties, surface state, specification model, and the like. The prepared standard sample tube is used to adjust the detection sensitivity of the eddy current instrument and determine the evaluation criteria. Before the test, the detection frequency can be pre-selected according to the relevant formula, and then the pre-made standard tube can be detected, so that the parameters can be corrected, thereby obtaining the optimal gain, the optimal phase, and the optimal frequency that can be used for detection. After determining the parameters such as the phase, depth, and artificial defects of the standard sample tube, these parameters can be used as the detection standard for the actual inspection of the copper tube to be inspected. When testing the sample tube to be tested, the phase angle of the defect signal of the sample tube to be tested can be detected by referring to the standard curve, thereby making a defect judgment. The difference between domestic eddy current testing and foreign eddy current testing is analyzed from two aspects: application scope and acceptance criteria.

a) Scope of application. In JB / T4730 predetermined eddy current testing for titanium and titanium alloy pipe having an outside diameter should be no greater than 30mm, the wall thickness of the pipe should be detected is not greater than 45mm; for copper and copper alloy seamless tube having an outside diameter shall not exceed 50mm, The wall thickness of the pipe to be tested should be no more than 3mm; other materials also need to meet this standard. For steel pipes, steel pipes with an outer diameter of not less than 4 mm can be tested.
French RCC-M MO6000 the predetermined wall thickness greater than 65mm to 075mm outside diameter less than or equal to less than 3mm pipe eddy current testing can be performed. Without clear pipe material, it can be understood that there is no requirement for material restrictions, and eddy current testing can be performed for both ferromagnetic and non-ferromagnetic.

As can be seen from the above description, there is described RCC-M relatively clear, ASME is more flexible, and B/T4730 thickness limit is not specified, the selection of detection may produce some effect, it should be noted.

b) According to the acceptance criteria. JB/T4730, RCC-M clear and ASME standards, and compared to a sample of artificial defect signal, if the signal of the lower pipe eddy current testing, the pipes are acceptable, but each has its own additional description thereof is stressed Where.

JB/T47306823 stipulates: After inspection, it is found that the depth of the pipe is larger than the standard compared with the standard defective pipe, then the flaw detection can be re-tested or verified by other detection methods. If it still exceeds the standard, then the pipe can be considered unsuitable for eddy current testing. That is to say, even if there is a signal exceeding the artificial defect, the pipe can continue to be used as long as it can be determined that the signal is not generated by the defect (other methods are used). This cautious approach demonstrates the high sensitivity and variability of eddy current testing.

The RCC-M emphasizes the edge effect of eddy current testing. The edge effect means that when the detection coil probe is close to the edge of the workpiece, the eddy current will be distorted and a strong interference signal will be generated. Therefore, RCC-MM3304 "Austenitic stainless steel pipes (excluding heat exchanger tubes) for Class 1, 2, and 3 equipments" emphasizes that the ends that cannot adequately perform eddy current testing need to be removed.

3. Eddy current testing process

![Figure 1. Testing process](image)

- a) Preparation before testing: copper tube cleaning and drying, standard probe production, standard probe production.
- b) On-site inspection: standard curve production, data acquisition and preservation.
- c) Data analysis: analysis of suspected signals and statistics of test results.
- d) Conclusion and recommendations: The unit is reset and turned on.
4. User's work schedule

Table 1. Work schedule

| Process     | Work content                                      | Remarks  |
|-------------|--------------------------------------------------|----------|
| Before testing | Remove the evaporator end cover                  |          |
|             | Clean evaporator condenser copper tube           |          |
|             | Blow dry evaporator condenser copper tube        |          |
|             | Prepare a set of 220 volt power supply (three eyes x2) | ≥1KW    |
|             | Prepare a few bottles of nitrogen on site        |          |
|             | Prepare a set of tables and chairs on site (putting computer and eddy current flaw detector) |          |
| Testing     | Arrange at least one person to cooperate with the test |          |
| After testing | Install the evaporator two end caps             |          |

5. Evaporator damage marking instructions

Table 2. Mark of damage

| Depth  | Coefficient | Mark of damage |
|--------|-------------|----------------|
| ≥60    | ≥10000      | Serious injury |
| ≥40    | ≥4000       | Heavier damage |
| ≥20    | ≥1000       | General injury |
| ≥1     | ≥10         | Minor damage   |
|        |             | No obvious damage |
| ≥40    | Number represents damage location (clock)       | Drum tube, probe pass |
| ≥20    | Number represents damage location (clock)       | Drum tube, the probe can pass |
| ≥1     | Number represents damage location (clock)       | Drum tube, the probe can pass |

- a) The main damage of the evaporator is the bulge. The reason for the bulge may be that the water temperature control of the unit is too low, and the partial evaporation temperature at the outlet of the evaporator expansion valve is too low, so that occasionally there is part of the icing condition in the part and the bulging condition is generated by the heat pipe.
- b) Individual heat exchange tubes may have wear at the support plate location.
- c) Some abnormal waveforms are yet to be verified.

6. Test results and treatment suggestions

A. Heat exchange tube damage
The damage of the heat exchanger tubes of the evaporator of the unit is mainly the mechanical damage of the inner wall; the loss of the heat exchange tubes of the condenser is mainly corrosion and impact damage.

B. Repair advice
- a) Overall replacement of the evaporator
- b) The condenser is recommended to be replaced

Figure 2. Schematic diagram of damage of heat exchange tubes
C. Reason statement
The evaporator of the unit has a relatively long use time, and the heat exchange tube has a slight deformation, and there is a large amount of damage in the form of an inward "bullet" near the inlet position. In addition, the thickness of the baffle plate of the evaporator is small, and the force is repeatedly applied during the extubation, and the deformation and the diameter of the hole are easily formed. After replacing the new pipe, the heat exchange pipe and the damaged baffle are in contact with each other, and it is easy to cause mechanical damage again in a short time.

The wall of the condenser heat exchange tube is thick, and the strength of the inner support plate is high, which can withstand the force of the extubation and the secondary expansion tube. After the heat exchange tube is replaced, it can continue to maintain normal use.

7. Conclusion
This paper studies the application of eddy current testing in the fault detection of a ship's SAB unit, mainly for the detection requirements of a ship's SAB unit in ship repair. The engineers of York Trading Co., Ltd. successfully solved the actual demand by using eddy current testing technology. And put forward a reasonable plan and reasons, which has a strong practical significance. It is worth mentioning that before choosing to purchase a set of eddy current testing systems, the components that are frequently inspected should be properly tested and evaluated. Some eddy current testing system suppliers will provide free evaluation and test reports to verify the feasibility of the test. Therefore, before purchasing and installing, first identify a trusted manufacturer and interact and cooperate with them in advance to clearly understand whether the eddy current testing equipment produced by the manufacturer is really suitable for the customer's future flaw detection work.

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