Development of Magnetic Flux Leakage Robot for Large-Sized Tanks Bottom Floor

Ho CHANG¹,*, Chou-Wei LAN² and Yu-Ting HSIEH¹

¹Graduate Institute of Manufacturing Technology, National Taipei University of Technology, Taipei 10608, Taiwan
²Material and Chemical Research Laboratories, Industrial Technology Research Institute, Hsinchu 31040, Taiwan

*Corresponding author

Keywords: Magnetic flux leakage, Robot, Corrosion defects, Hall magnetic sensor.

Abstract. This study develops a wheeled robot with magnetic flux leakage testing device. This testing robot is designed to detect the corrosion-oriented defects on the bottom plates of large-sized tanks at petrochemical plants. A Hall-effect encoder is used to achieve the function of location detection. Besides, the magnetization device consists of NdFeB permanent magnets and silicon steel sheets, with the detection probe adopting Hall magnetic sensor. Experimental results show that the magnetic flux leakage testing device is highly reliable as it can accurately detect defects sized 2 mm and being 4 mm deep on the surface of a S20C steel plate being 10 mm thick. Besides, with a S20C steel plate being 5 mm thick, the device can detect defects sized 2 mm and being 2 mm deep on the front and reverse sides.

Introduction

Traditional practice is to empty and clean the tank first, and then enter the tank and use different NDT methods to detect the corrosion condition of the tank. But this practice is both time and money consuming. Magnetic flux leakage (MFL) testing is one of the most reliable methods to detect corrosion on the surface of double sides of tank bottom plates, and is used as a corrosion inspection technique in the petrochemical industry [1-4]. This MFL detection system is designed to collect information about the state of the tank floor, providing information about the existing level of corrosion. Certain defects are to be repaired in order to increase the remaining life of the tank [5-9].

Currently, inspection of welds and defects in a tank is carried out manually by first emptying and cleaning the tank. This is a time-consuming and expensive operation that requires operators to enter a hazardous environment. In fact significant cost reduction could be made by using robots to carry out automated inspection and letting robots access to the welds and defects [10-14]. This study attempts to develop a magnetic flux leakage testing robot that possesses advantages of these two kinds of device, and then makes quantitative analysis of the detected defect signals.

Experimental Details

This study uses permanent magnet, neodymium iron boron (NdFeB) magnet, as the magnet source. The reason for the study to select the permanent magnet for magnetization is that it has many good features, such as its high magnetic energy product, small volume, light weight, no power required, great coercivity after magnetization of magnetic material, and easy for detecting. Besides, the study selects silicon steel sheet with excellent magnetism as the magnetic yoke, and performs magnetic air-gap adjustment using nuts and bolts in order to adapt to magnetic saturation depth of the tested objects with different thicknesses. The detection probe used by the study is Hall magnetic sensor. Figure 1 shows the structure for the overall control system of the magnetic flux leakage testing robot developed by the study. The control system is mainly divided into two systems: power drive system.

315
and detection/monitoring system. Power drive system is mainly responsible for moving the magnetic flux leakage testing robot. It has to overcome the robot’s effects of its weight and magnetic attraction force so as to let the robot move freely on storage tank bottom floor. Matching Arduino UNO evaluation board with L298N motor driver board, the study uses PS2 joystick to control the forward and reverse spinning of DC motor, and then transmits the signals of Hall encoder to the computer. As to detection/monitoring system, it is mainly responsible for the magnetic flux leakage testing robot’s ability to detect corrosion defects. Besides, matching Arduino Mega 2560 development board with the detection probe, Hall magnetic sensor, the study transmits the detected magnetic leakage field signals to the human-machine interface of LabVIEW in computer to display its waveform curve, so as for inspector to judge the extent of corrosion timely. Figure 2 is a diagram of the physical form of the magnetic flux leakage testing robot developed by the study.

![Diagram of the physical form of magnetic flux leakage testing robot.](image)

**Figure 1. Schematic diagram of the structure of the control system of magnetic flux leakage testing robot.**

**Figure 2. Diagram of the physical form of magnetic flux leakage testing robot.**

**Results and Discussion**

Figures 3-5 show the waveforms for the detected magnetic leakage field signals of the defects on front and reverse sides of steel plates Nos. 1-7. The study compares the magnetic leakage field signals of the defects on the front side of steel plates Nos. 1-7, and finds from the waveform curve of magnetic leakage field signals that as the defect depth is greater, the voltage waveform is also greater. Besides, in Figures 3(b) and 4(b), only 4 obvious voltage waveforms appear, implying that only 4 defects are detected. And in Figures 5(b), only 3 obvious waveforms appear, also implying that only 3 defects are detected. These phenomena indicate that for the defects having greater distance from the magnetic device and having smaller widths, it is not so easy to detect their magnetic leakage field signals.
Figure 3. Waveform of magnetic leakage field signals for the defects of steel plate No. 1: (a) defects on the front side; (b) defects on the reverse side.
Figure 4. Waveform of magnetic leakage field signals for the defects of steel plate No. 2: (a) defects on the front side; (b) defects on the reverse side.

Figure 5. Waveform of magnetic leakage field signals for the defects of steel plate No. 3: (a) defects on the front side; (b) defects on the reverse side. Conclusions

Conclusions

This study developed a wheeled robot with magnetic flux leakage testing device to detect the corrosion-oriented defects on the bottom plates of large-sized tanks at petrochemical plants. The prepared robot mainly consists of a power drive system and a detection and monitoring system. The power drive system drives 2 DC motors by combining an Arduino UNO evaluation board with an L298N motor driver board. In addition, the magnetization device consists of NdFeB permanent magnets and silicon steel sheets, with the detection probe adopting Hall magnetic sensor. Experimental results show that the magnetic flux leakage testing device is highly reliable as it can
accurately detect defects sized 2 mm and being 4 mm deep on the surface of a S20C steel plate being 10 mm thick. When magnetic flux leakage testing robot is actually applied to quantitative analysis of detected defects on storage tank bottom floor, if the $D_{P-P}$ values and $V_{P-P}$ values of the waveforms of defect signals are known, the inspector can deduce the thickness of defects, and then find the defect depths from the corresponding $V_{P-P}$ value.

Acknowledgments

The authors would like to thank the Ministry of Science and Technology of the Republic of China, Taiwan, for financially supporting this research under Contract No. NSC 103-2221-E-027-082.

References


[7] Zhijun Y.; Guang D.; Wei, Li.; Yanbiao J. Research on magnetic flux leakage signals quantity technology of tank floor corrosion defects based on artificial neural network, 2009, Fifth International Conference on Natural Computation, Tianjin, China, 245-249.


