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MAGNETIC FLUX LEAKAGE BASED ON-LINE MEASUREMENT TECHNOLOGY FOR SURFACE AND SUBSURFACE FLAWS DETECTION IN HEAVY STEEL PLATES

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ABSTRACT

This paper presents a measurement technology to detect surface and subsurface flaws in heavy steel plates. This method is related to a magnetic flux leakage (MFL) widely used in the inspection of flaws in pipeline and storage tank. The MFL measuring system including element technologies such as multi-channel magnetic sensors and high-speed signal processor has been developed for use in the manufacturing process. Pilot tests were conducted for detecting surface and subsurface flaws, and detecting material property deviations. Interesting results were obtained, and how to utilize them in the future will be discussed.

Keywords: MFL, heavy plate, invisible flaw

1. INTRODUCTION

In the steel industry, heavy plates are one of the major steel products and are used in various applications such as shipbuilding, structures, pipeline, and pressure vessels. Recently, new products capable of being utilized under the harshest conditions like off-shore application have been actively developed to meet customer needs. As customers' quality requirements continue to rise sharply, claims for quality are increasing.

The key factors for quality control of a heavy plate are chemical ingredients, materials, dimensions, shapes, surface and internal quality, and depending on usage, weld-ability, workability, heat resistance and corrosion resistance may be additionally requested. This research focuses on the development of a detection system to inspect surface and subsurface flaws in heavy plates.

This paper deals with magnetic flux leakage measurement technology for inspecting invisible flaws in heavy plates. As a technique for inspecting surface of plate, an optical camera and illumination has been widely used [1-3]. In this paper, an effective flaw detection method capable of detecting not only surface defects but also invisible defects called subsurface defects in heavy steel plates is introduced.

2. Magnetic Flux Leakage Method

Magnetic Flux Leakage technology is one of the representative NDT methods used to detect flaws in steel structures.

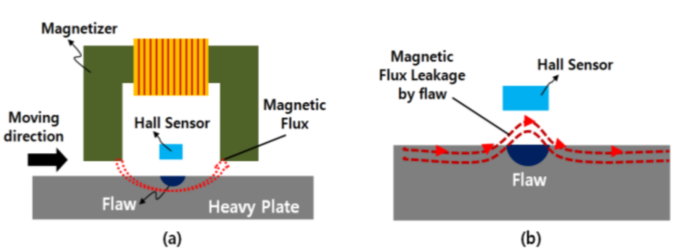

FIGURE 1: Measuring Principle of MFL (a) Basic configuration consisting of magnetizer and magnetic sensor (b) Magnetic flux leakage by flaw

2.1 MFL Measuring Principle

Basically, a powerful magnetizer like magnet or electromagnet is used to magnetize the heavy plate as in figure 1(a). At area where flaw is in figure 1(b), the magnetic field leaks from the surface. The hall sensor placed between the poles of the magnetizer detects the magnetic leakage field. The surface or subsurface flaws in a heavy plate can be inspected as described above.

2.2 Development of MFL based Measurement System

For on-line measurements of magnetic flux leaked by the surface or subsurface flaws of a plate at about 1 m/s speed, the following elemental techniques have been developed as shown in figure 2 (a): 1) MFL measuring Module is linearly-integrated hall element sensor, electronic circuits, and magnetizer for measuring a specific effective width at one time, 2) Signal processor converts a number of analog signals measured in a multichannel sensor into digital signals, processes by an algorithm in the microcontroller, and transmits the digitalized data to the computing PC via TCP / IP communication, 3) HMI & Anlaysis visualizes the measured result and detects the suspected area. 4) Mechanical unit is designed so that the signal can be measured stably. Figure 2 (b) shows the on-site testing using the developed system. For on-site testing, when the target plate passes below the MFL measuring unit, the sensor is lowered by the mechanical unit and scans the surface of the target material.

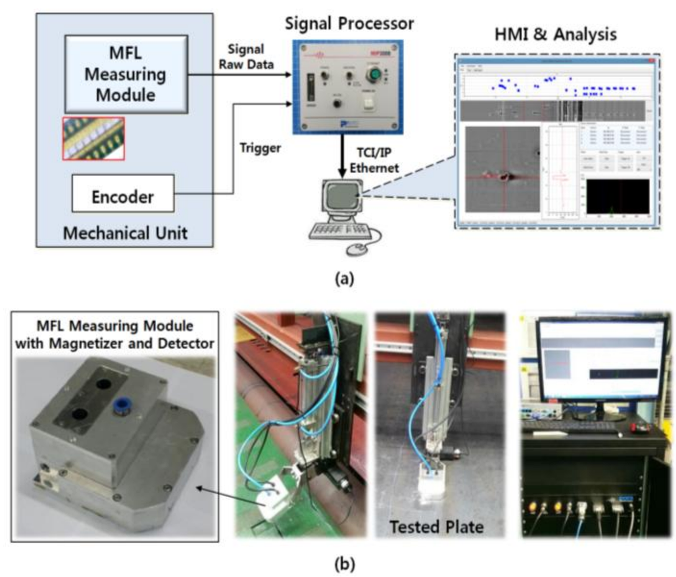

FIGURE 2: Developed MFL Measurement Equipment (a) System configuration (b) Actual pictures of MFL measuring module and field testing.

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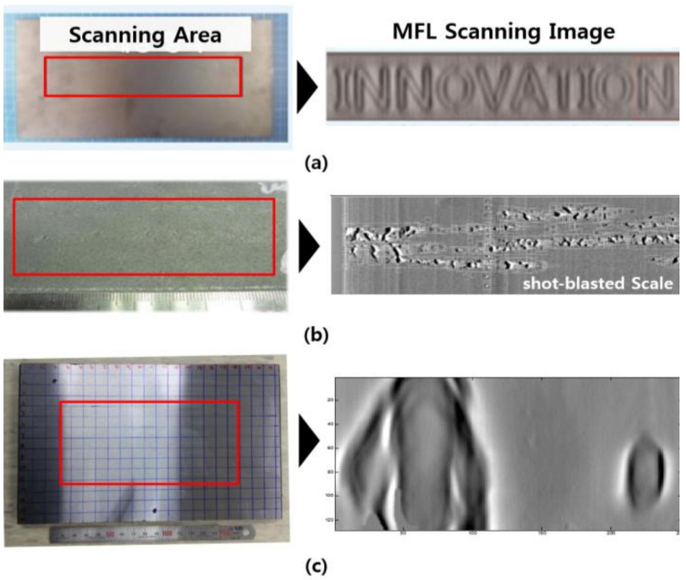

FIGURE 3: Test Results by developed MFL system with samples: (a) Lettering with laser processing, (b) descaled surface by Shot-blast and (c) non-uniform material property by heat treatment.

3. RESULTS AND DISCUSSION

We have tested the inspection performance on surface and subsurface defect samples as shown in figure 3.

Figure 3 shows INNOVATION in MFL scanning image. The surface of the sample was laser-processed with INNOVATION. The small groove formed by the laser is well measured by MFL system. Figure 3 (b) shows the result of measuring the scale defects occurring on the surface of the plate. Although it can not be confirmed with optical camera, it is measured well by using MFL. Finally, the MFL test was carried out with the sample with the non-uniform material property by heat treatment. As shown in Fig. 3 (c), it was confirmed that the leakage magnetic flux become strongly visible in the boundary region where the material properties, i.e. hardness, have changed by rapid heating and quenching.

The MFL inspection system has a high performance on detecting surface and subsurface flaws in heavy steel plate though an optical inspection system can not detect. If we can get 2D MFL image information from the surface of heavy plates in the steel manufacturing process by applying a high resolution linear array type hall element sensor, the flaw detection and classification function can be relatively easily implemented by adopting advanced image processing technology such as Deep Learning Neural Network.

4. CONCLUSION

We have proved the excellent performance of MFL-based on-line measurement technology by using a high resolution linear type hall element sensor and image processing technology in the field of surface and subsurface flaw detection in heavy steel plates.

As there may are a lot of pseudo flaws in the real manufacturing situation, we are going to apply Deep Learning Neural Network algorithm to classify real flaws from pseudo ones.

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