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The MFL technique for surface flaws of weld zone with residual magnetization method

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Abstract

In the present study, the three components of the residual leakage magnetic fields from the flaws were measured with the MI sensor. Furthermore, finite element analysis for the three components of the residual magnetic fields was carried out. From these experimental and analytical results, *By* showed the two pairs of the maximum and the minimum and can evaluate the flaw length. In the case of the measurement using the residual magnetization procedure to the test pieces with the butt weld, the signal contained the noise from the weld metal and the geometry of the weld zone. Therefore, the wavelet transform signal processing was applied to the signal for the cancellation of the noise.

Keywords：MFL testing , residual magnetization, wavelet transform, weld zone

1. Introduction

The magnetic flux leakage testing with residual magnetization has been researching by some groups[1]-[4]. The residual magnetization would have good detectability because magnetization equipments are not used in the measurements. According to our previous works [3]-[4], Magneto-impedance(MI) sensor which has high resolution and high sensitivity was used for measuring the residual magnetic field arising from the flaws. After the wavelet decomposition and reconstruction techniques were applied for cancellation of noise, the quantitative evaluation method for surface flaws in test pieces has been presented.

In the present study, the three components of the residual magnetic field for the test pieces with/without the butt welds were measured to improve the flaw size evaluation. Furthermore, finite element analysis for the three components of the residual magnetic fields was carried out. From these experiment and analytical results, the detectability of the surface flaws in the test pieces with the butt welds was discussed

2. Test pieces, the experimental procedures and the theoretical analysis

2.1 Test pieces

The main target of this study is the inspection for weld zone in bottom floors of oil storage tanks. Therefore, we used mild steel plates of 200 mm in width, 300 mm in length and 9 mm in thickness as the test specimens. Furthermore, the test piece with the butt welds of 1000 mm in length, 400mm in width and 9 mm in thickness was used. The surface of the test piece with the butt weld was covered with the coating of 0.6mm in thickness. As the flaw model for cracks generated in the weld zone of the bottom floors, artificial flaws in the surface of test specimens with /without the butt weld were made by Electric Discharge Machining (EDM). These artificial flaws are parallelepiped flaws of about 0.5mm width having various lengths and depths.

2.2 Experimental procedures

The experimental setup consisting of a MI sensor (Aichi Steel Co.), a controllable sensor positioner and a test specimen is shown in Fig.1. The measurements of residual leakage magnetic field distributions have been done by using a MI sensor which has an active area of 3mm × 4mm. After the test pieces were magnetized with an electrically magnetizing yoke (5200AT, Nihon Kensa Kizai Co.) by direct current 9A in *x* direction which was perpendicular to the flaw length, area of 40mm × 40mm around flaws was scanned with MI sensor which was moved by controllable sensor positioner in speed 4.7 (mm/s). The three components of residual leakage magnetic fields in the upper spatial domain have been accurately measured and were stored into a personal computer.

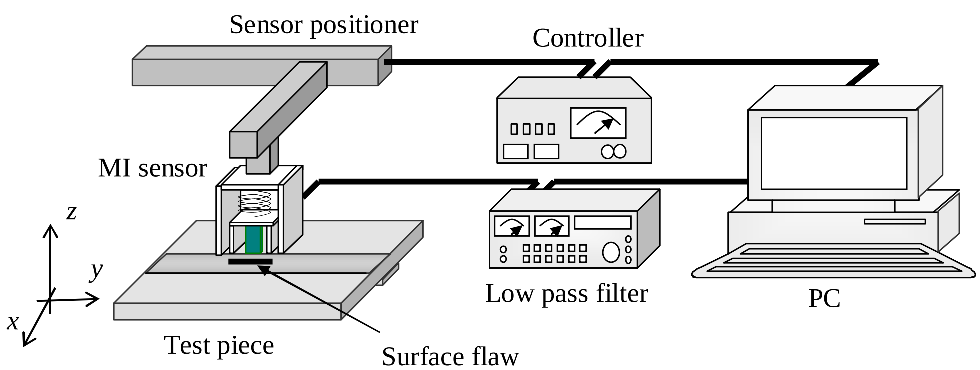


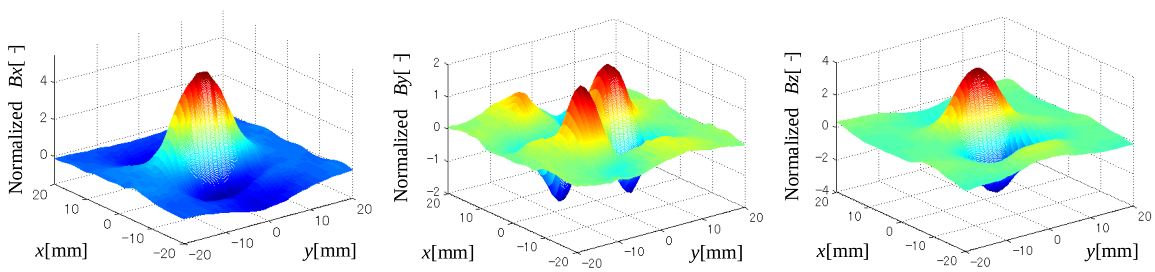
Fig. 1 The experimental setup for the residual leakage magnetic fields arising from flaws

2.3 Theoretical analysis of the three components of the residual leakage magnetic fields

The three components of the residual magnetic leakage fields have been analyzed using the finite element method. The software used by the analysis was MagNet (Infolytica Corp.). The analytical model was the same as the experimental condition. The *B-H* curve for the mild steel was measured to obtain the intensity of the residual magnetic field and the magnetization of 0.8 T was applied to the test pieces in the analytical model to simulate the residual magnetization condition.

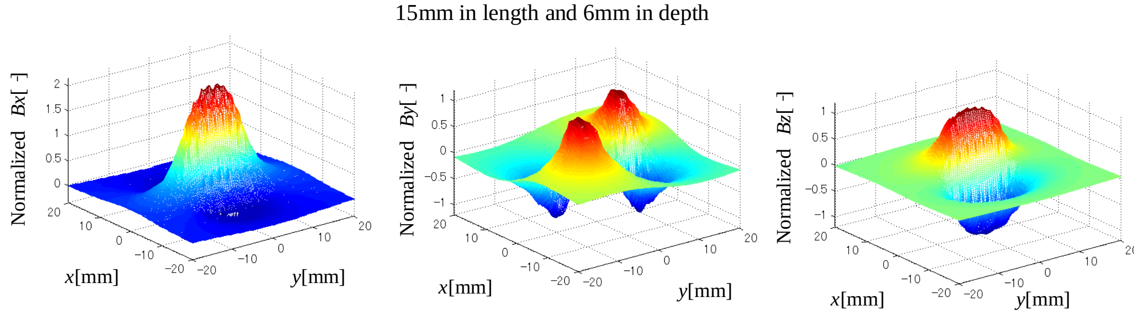
3. Experimental and analytical results and discussion

Measurements of *Bx*, *By* and *Bz* were conducted by scanning with the MI sensor in spatial domain around flaws. The measured results contained the low and high frequency noise. Therefore, Wavelet decomposition and reconstruction techniques were carried out for cancellation of these noises. After the signal processing, the distribution profiles of *Bx*, *By* and *Bz* vs sensor's position were obtained as shown in Fig. 2. Fig. 3 shows the analytical results for the flaw of 15mm in length and 6mm in depth. The amplitude of the flaw signals in these figures normalized by the amplitude of the experimental and the analytical results obtained from the flaw of 0.5mm in width, 5mm in length and 2mm in depth respectively. As can be seen from these results, *Bx* showed the maximum at the center of flaw and *Bz* showed to be symmetric with respect to the center of parallelepiped flaws. These components are usually used for the flaw size evaluation. Interestingly, *By* showed the two pairs of the maximum and the minimum, which were the end points of the flaw length. This experimental finding coincided with the reference [5]. The several data for the flaws with various lengths was measured and the fｌaw length with respect to the distance between the pairs of the maximum and minimum was arranged. The correlation was excellent and the flaw length can evaluate from the *By* distributions.



(a) *Bx* (b) *By* (c) *Bz*

Fig. 2 The experimental results measured from the flaw of 0.5mm in width, 15mm in length and 6mm in depth

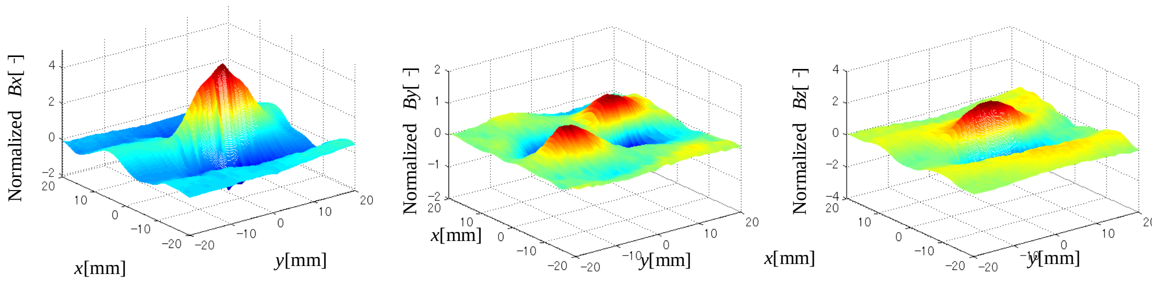


(a) *Bx* (b) *By* (c) *Bz*

Fig. 3 The analytical results for the flaw of 0.5mm in width, 15mm in length and 6mm in depth

4. Measurement for the flaw in the test piece with the butt weld and the coating

Bx, *By*, and *Bz* was measured for the flaws in the test piece with the butt weld and the coating. The signal processing was applied to the obtained data as well as the results of Fig.2. The processed data was still containing the signal generated from the butt weld. The cancellation of the butt weld signal was carried out by subtracting the signal measured from the test piece without the flaw. They are shown in **Fig. 4**. The amplitude of the flaw signals in the figure normalized by the same amplitude used in of Fig. 2. As a result, the flaws made by EDM in the butt weld were detected by using the three components of the residual leakage magnetic fields. The research of the flaw size evaluation method for surface flaws in the test piece with the butt weld is underway.



(a) *Bx* (b) *By* (c) *Bz*

Fig. 4 The experimental results measured from the flaw of 0.5mm in width, 18mm in length and 6mm in depth in the test piece with the butt weld

5. Conclusions

The three components of the residual leakage magnetic fields arising from the flaws were measured with the MI sensor. *By* showed two pairs of the maximum and the minimum, which were the end points of the flaw length. It was suitable for the flaw length evaluation. Moreover, the test specimen with the butt weld and the coating were measured by the MI sensor. It was clear that the flaws were detected by the cancellation of the butt weld signal and the signal processing.

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