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Magnetic imaging by ultrasonic techniques
超音波技術による磁性イメージング

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1. Introduction

Imaging of magnetization in materials has been performed with a variety of techniques: for instance, scanning methods with sensitive magnetic sensors[1-3], electron microscopy techniques in which modification of electron motion due to Lorentz force is detected[4] and optical methods through the Kerr effect[5]. These techniques are powerful tools to visualize magnetic field distribution with a high spatial resolution, but surface analysis of objects is mainly targeted.

Here we report magnetic imaging by ultrasonic techniques, in which acoustically stimulated electromagnetic (ASEM) radiation is probed[6]. In this new scheme, we sensitively measure electromagnetic radiation arising from electromagnetomechanical coupling of an object. Through the ASEM method, we demonstrated nondestructive magnetic tomography as well as the two-dimensional (2D) mapping.

2. Method and Sample Preparation

Figure 1 shows the measurement setup[6]. A target sample is placed in a focused zone at a distance (40 – 60 mm) from a 10MHz transducer. Rectangular 50nsec wide pulses are applied at a repetition rate of 100 - 500 Hz by a pulser/receiver (Panametrics - NDT, 5077PR). As well as standard echo signals, electromagnetic radiation is measured through a loop antenna tuned into a center frequency of ultrasonic waves. These signals are fed to low-noise preamplifiers and averaged by using digital oscilloscope. By moving the transducer with an XY-stage, the focused ultrasonic beam scans over the whole area of samples.

In order to demonstrate magnetic imaging, we prepared a plate of austenitic stainless steel (9.9mm×26.4mm×0.5mm). It is known that magnetization is induced in austenitic stainless steels by external stress or distortion[3]. We have thus folded the plate in the middle and compared the imaging result with that of the original one. Furthermore, we have also performed nondestructive tomography through the ASEM method. To this end, we prepared an optically transparent phantom (a block of gel), where several pieces of nonmagnetic metal (aluminum) and ferrite are embedded.

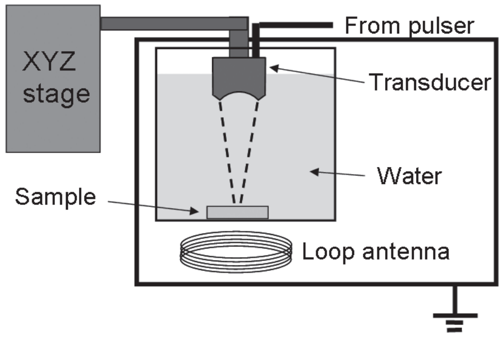

Fig.1 Schematic diagram of measurement setup

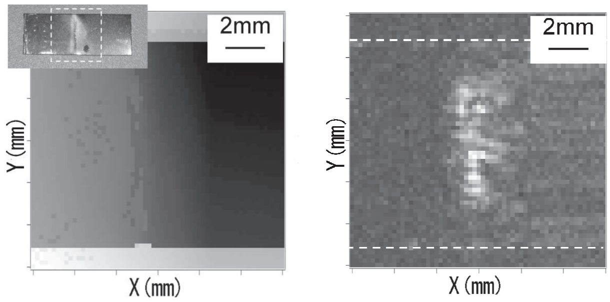

Fig.2 2D imaging results in a folded plate of austenite stainless steel. The plate is folded at the central part. The left figure represents a standard echo image in which the delay time of echo signals are plotted at each point (the brighter color corresponds to longer delay time). The right one shows a mapping obtained by the ASEM method (the brighter color indicates higher signal intensity). An inset in the left figure is photograph of the sample measured. The white dashed line shows the imaged area.

3. Magnetic Imaging via ASEM Response

It is tempting to compare the results of ASEM measurements with standard ultrasonic images. **Figure 2** shows 2D images in a plate of austenitic stainless steel. The spatial resolution in the XY plane is estimated to be about 1 mm, determined by a size of the beam spot (about 0.7 mm). ASEM signals are definitely probed along the folded line (right figure) while significant change of echo delay time is not found (left figure). We suppose that the

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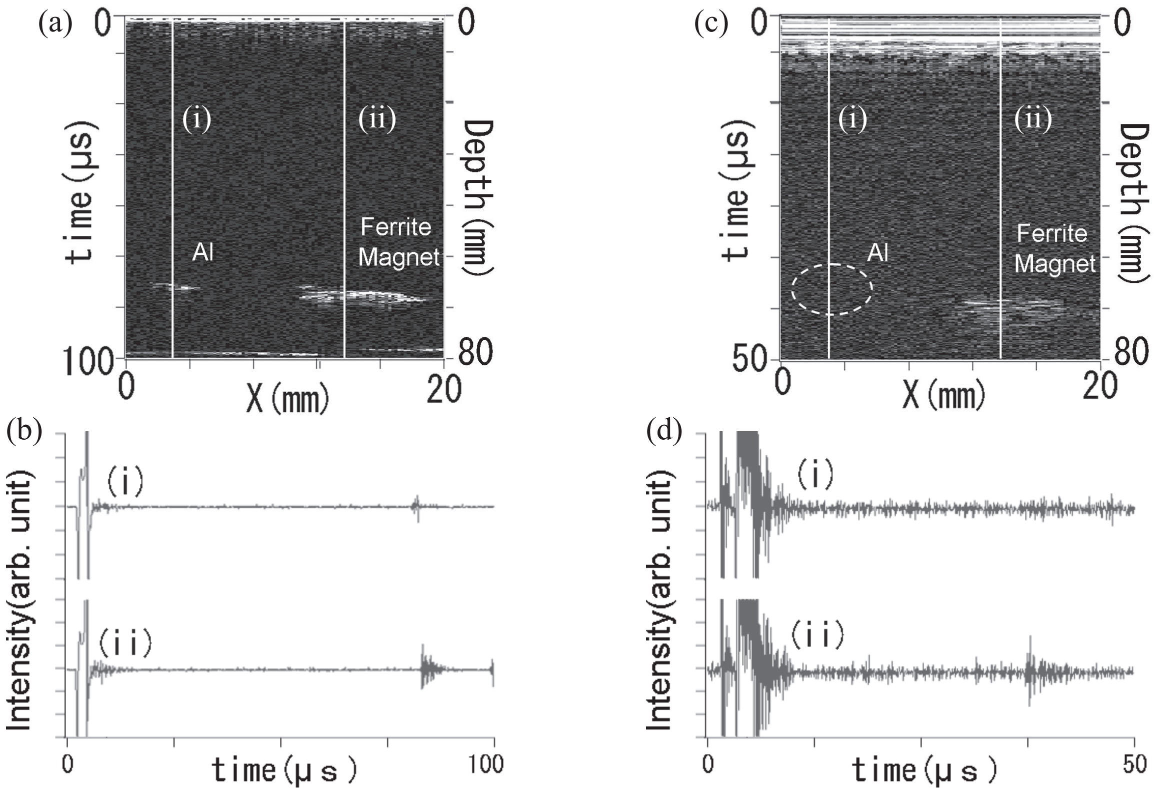

Fig.3 (a) Tomographic image in the standard echo method. (b) Real-time waveform of echo signals at two positions shown as the white line (i) and (ii) in (a). (c) Tomographic image in the ASEM method. The dashed circle indicates the location of Al detected by the echo method. Nonmagnetic materials (Al) are well eliminated in the ASEM method. (d) Real-time waveform of ASEM signals.

observed ASEM signals originate from the presence of magnetization induced by the external distortion, since no discernible ASEM signal is detected before folded. It will be interesting in the next stage of experiments to investigate in more detail the mechanism of ASEM radiation from stainless steels.

Figure 3 shows typical tomographic images of the phantom. The depth in Fig. 3(a) and 3(c) is unified by a factor of 2 because the response time of ASEM signals is a half of echo delay time. The phantom is surrounded completely with a large loop antenna, avoiding extrinsic contrast due to reduction of signal intensity at positions distant from antenna. While two different pieces are observed in the echo measurements (Fig. 3(a) and 3(b)), nonmagnetic materials (Al) are well eliminated in the ASEM tomography (Fig. 3(c) and 3(d)).

4. Conclusion

We have experimentally realized magnetic imaging via ultrasonic excitation. One of the most useful features in the ASEM method is high compatibility with existing ultrasonic techniques. Given the feature of nondestructive tomography, the method may find a rich area of application.

Acknowledgment

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References

1. A. M. Chang, H. D. Hallen, L. Harriott, H. F. Hess, H. L. Kao, J. Kwo, R. E. Miller,R. Wolfe, and J. van der Ziel: Appl. Phys. Lett. **61** (1992) 1974.
2. L. N. Vu, M. S. Wistrom and D. J. Van Harlingen.: Appl. Phys. Lett. **63** (1993) 1693.
3. M. Oka, T. Yakushiji, and M. Enokizono: IEEE Tran. Magn. **37** (2001) 2045-2048.
4. M. Cohen: IEEE. Trans. Magn. **1** (1965) 156-167.
5. For instance, W. K. Hiebert, A. Stankiewicz, and M. R. Freeman: Phys. Rev. Lett. **79** (1997) 1134-1137.
6. K. Ikushima, S. Watanuki and S. Komiyama: Appl. Phys. Lett. **89** (2006) 194103.