Non-destructive inspection using acoustically stimulated electromagnetic method

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Many steel materials exhibit hysteresis in the variation of magnetic flux density $\boldsymbol{B}$ with respect to magnetic field $\boldsymbol{H}$. Because the hysteresis curve contains a number of independent parameters that is sensitive to factors such as stress, strain, grain size and heat treatment, they have been used in the determination of material properties in nondestructive evaluation (NDE). Although ultrasound waves can propagate through optically opaque substances, the majority of existing ultrasound techniques are restricted to determining the mechanical properties from the elasticity or mass density of a target. Recently, however, magnetic properties have been successfully measured and visualized by ultrasonic excitation[1-4)]. The principle of this technique is based on the generation of acoustically stimulated electromagnetic (ASEM) fields through magnetomechanical coupling. In the ASEM method, the spatial resolution of magnetic imaging is determined by ultrasound focusing, not limited to the size of magnetic sensors or the distance between the sensor and an object (lift-off).

The ASEM measurement setup is shown in Fig. 1(a). An ultrasound transducer with an acoustic delay line is used for avoiding the EM noise generated by the transducer. A specimen is subjected in external magnetic fields $\boldsymbol{H}$ which is applied by a commercial electromagnetic coil. The ASEM signal emitted from a specimen is picked up through a resonant loop antenna tuned to the ultrasound frequency.

We measured magnetic hysteresis curves and visualized the magnetic-flux distribution in a steel plate[3)]. The monotonous ASEM intensity over the scanned area is observed in a defect-free plate (Fig.1(b)), while a clear contrast of the ASEM intensity is widely observed in the plate with a defect (Fig.1(c)). This result indicates that a magnification effect due to magnetic flux distribution. We should note that the minimum detectable size of defects is not limited to the size of the ultrasonic focal spot due to the magnification effect, which is beneficial for NDE. Magnetic-flux probing by ultrasonic waves is thus expected to be a viable method of nondestructive material inspection.

Figure 2 represents the stress dependence of local hysteresis loop measured by the ASEM method. The hysteresis loop changes clearly under tensile stress, indicating that local hysteresis quantities such as coercivity will be a promising parameter as an index of quantitative evaluation of stress.

References
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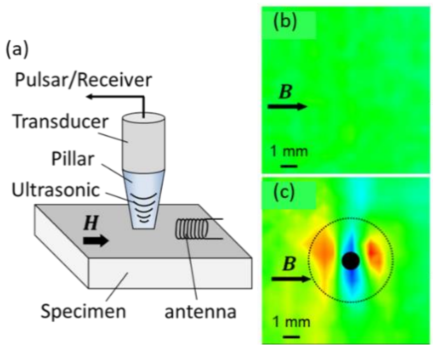

Fig. 1 (a) Measurement setup and ASEM image for a steel plate (b) without and (c) with an artificial defect.

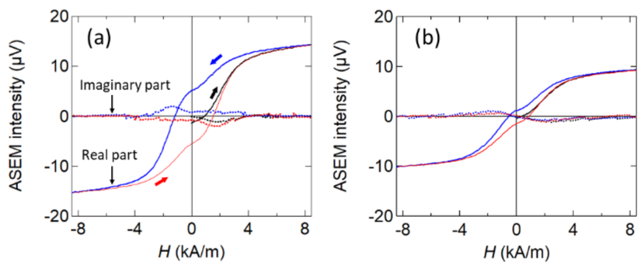

Fig. 2 Stress dependence of the ASEM hysteresis loop at (a) 0 MPa and (b) 333 MPa.