Mechanism study of Directivity of TR probe for Eddy Current Testing of Magnetic Structural Material

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Eddy Current Testing signals of the transmission/receiver (TR) type probe can be influenced by the directivity of the probe. In the previous study, ECT signal change due to scanning angle was evaluated in ferromagnetic material using a TR type probe, but the mechanism of the change is still not clear. In this study, ECT is conducted changing the orientation of the TR probe both on carbon steel and on austenitic stainless steel, to investigate the mechanism. The results show that the directivity of the probe is different on these two materials due to the existence of magnetic flux leakage. Also, the tendency of ECT signal with magnetism is clarified by the relationship between orientation and amplitude.

Keywords: eddy current testing, carbon steel, austenitic stainless steel, TR probe, orientation of probe, ferromagnetism, magnetic flux leakage

1. Introduction

Eddy current testing (ECT) is one of the most common nondestructive testing methods to evaluate cracks. Transmission/receiver (TR) type probe is one of the probes, which has two sets of coils with one for exciting magnetic field and another for receiving signals. ECT signals obtained by the TR probe has less noise compared to a pancake probe by separating pick-up coils from exiting coils.

In the previous study [1], the effect of scanning orientation was evaluated in non-ferromagnetic material JIS SUS316L using an arrayed-coil ECT probe. However, there are few studies to investigate the dependence of magnetism of target materials on the directivity of the TR probe.

This study aims to investigate the dependence of magnetism of target materials on directivity. For this purpose, ECT is applied both on ferromagnetic and non-ferromagnetic materials with changing the scanning angle. The tendency between angle and signal amplitude is measured. Furthermore, the mechanism of the signal change is discussed.

2. Experiment

To verify the directivity of ECT signals, ECT was applied both on carbon steel JIS SM490 (a ferromagnetic material) and austenitic stainless steel SUS316 (a non-ferromagnetic material). The size of these two specimens are 200 × 200 × 20 mm3(length × width × thickness), and the slit is in the center of the specimen and length, width and depth of the slit are 200 mm, 0.3 mm, and 0.1 mm, respectively.

In the experimental setup, the sinusoidal signal is generated in the function generator and output to the exciting coil. The voltage induced in the pick-up coil was measured by a lock-in amplifier with the reference signal of the function generator and recorded by a computer after AD conversion finally.

ECT was conducted using the TR probe, of which the distance between the center of exciting and pick-up coils is 5.0 mm. The dimension and the number of turns of coils are shown in Fig. 1 (a). The angle of the probe θ was defined as the one between the centerline of the slit and joint line of two coils, as shown in Fig. 1 (b). The x-axis was set perpendicular to slit, and the origin of x-axis and x position were difined as the center of the slit and the center of the exciting coil, respectively. ECT signal was obtained by scannning the specimen from $x = -10$ to 10 mm. Totally seven measurements were carried out for a specimen changing the angle θ from 0° to 90° by every 15°. The lift-off and frequency were set to 0.3 mm and 25 kHz.

3. Results and Discussion

For each specimen, the obtained ECT signal when the angle $\theta = 0°$ was rotated and augmented to be (0, 2) on the V_x-V_y plane, and all other signals were calibrated based on the transformation matrix used at this procedure.

To compare the characteristics of ECT signals of two steel specimens, the relationship between angles and the maximum amplitudes for SUS316 and SM490 are shown in Fig. 2.

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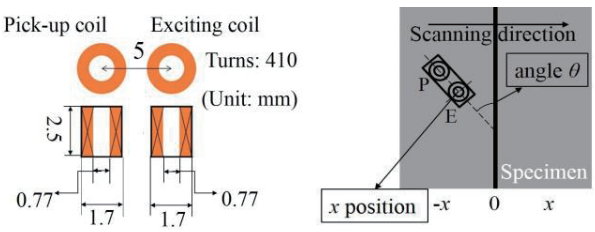
In the case of SUS316, the maximum amplitude decreases with the angle increases from 0° to 90°, since the distance between the pick-up coil and slit increases. In contrast, the amplitude does not decrease monotonously in SM490. The amplitude is minimum when $\theta = 30°$ while the amplitude is maximum when $\theta = 90°$.The results for two specimens are explained as that the magnetism of SM490 and SUS316 are different. For SM490, in the slit area, the magnetic flux lines are bent due to the increase of magnetic resistance. As a result, some lines leak out of the specimen surface, and this phenomenon is so-called magnetic flux leakage (MFL).

When the scanning angle was 90°, the distribution of the magnetic flux density is shown in Fig. 3, which was computed based on the reduced magnetic vector potential A_r method[2]. The magnetic flux density was detected at the 0.14 mm height above the surface of SM490 when setting x position of the exciting coil at 4 mm. It is clarified that both real and imaginary parts of the x-component (B_x) in magnetic flux density reached the maximum value around the center of the slit, which indicts the magnetic flux flows above the slit. In case of the z-component of the magnetic flux density (B_z), the signs of both real and imaginary parts change once around slit region, due to the fact that the orientation of the magnetic flux transforms once above the slit region. Considering the influence of MFL takes a major part in the components of magnetic flux density, the distribution of B_x and B_z are amostly symmetrical about the $x = 0$ and the origin, respectively. As a result, the existence of MFL is proved in the ferromagnetic material SM490.



(a) Dimension of coils **(b) Angle of TR probe**

Fig. 1 TR probe.

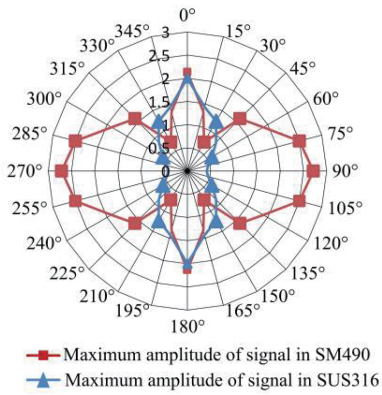
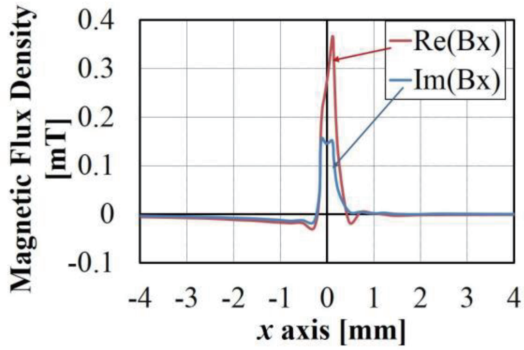
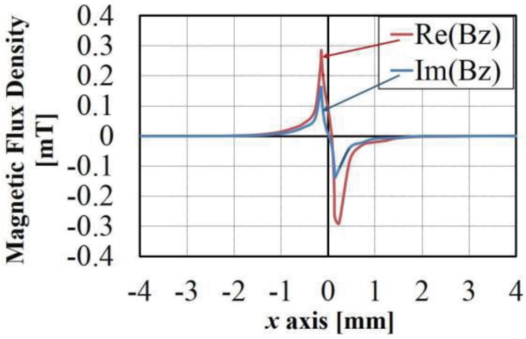


Fig. 2 Relation between angle and maximum amplitude of signals.



(a) Distribution of B_x



(b) Distribution of B_z

Fig. 3 Distribution of magnetic flux density near slit region when θ = 90°.

In contrast, SUS316 cannot generate MFL due to its non-ferromagnetic characteristic. Accordingly, the magnetic field could only be generated by the secondary circuit for SUS316, while in case of SM490, magnetic field could be generated by both secondary circuit and MFL.

4. Summary

In this study, ECT was applied to evaluate directivity of ECT signals of carbon steel SM490 and authentic stainless steel SUS316 by using the TR probe. The amplitude of ECT signals obtained for SM490 is not monotonously decreasing with increasing the angle to 90°, while the signal of SUS316 shows monotonic decrease. This difference comes from the effect of MFL. In addition, verification of the MFL effect on ECT signal is important for detection and sizing of crack.

References

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