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# Development of Guided Wave Inspection Technique Using Novel FeCo-based Magnetostrictive Material for CFRP Plates

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## 1. Introduction

Carbon fiber reinforce plastic (CFRP) can be processed into a variety of shapes, taking advantage of properties of the carbon fibers. For this reason, CFRP is increasingly used for products in various fields, such as automotive and aerospace parts. However, CFRP has a complex structure consisting of the fibers and base matrices, which limits the inspection range of ultrasonic testing, because of severe attenuation of ultrasonic waves in the CFRPs. We have developed a nondestructive inspection technique for CFRP plates, focusing on ultrasonic guided waves, which can propagate long distances[1)]. Previously, it is shown that conventional guided wave testing using SH (Shear Horizontal) waves with nickel as a magnetostrictive material had an inspection range of about 1.5 m on the CFRP plate[2)]. In this study, we examined two guided wave inspection techniques by using a novel FeCo-based magnetostrictive material that has a stronger magnetostrictive effects than nickel, which is one of conventional magnetostrictive material[3)], for wide area inspection.

## 2. Sample and guided wave transceive experiments

2.1 Sample As a sample, a CFRP plate of 300 mm in length, 1000 mm in width, and 3 mm in thickness was used. The CFRP consists of cross-ply laminated carbon fibers and epoxy resin. To generate magnetostrictive guided waves in the plate, novel FeCo-based magnetostrictive material thin films developed by Tohoku Special Steel Co. were used. This material has strong anisotropy. It is known that when a magnetic field perpendicular to the bias field is applied to the material, it produces a magnetostriction of approximately 30 ppm, which is equivalent to that of nickel. When a parallel magnetic field is applied instead, magnetostriction of up to about 90 ppm is generated.

2.2 Guided wave transceive experiments

Following two experiments were conducted. In the both experiments, the novel magnetostrictive material thin films were commonly used by gluing them in the short-hand direction. In the first experiment, an excitation field perpendicular to the bias field was applied as shown in Fig.1(a). A group of permanent magnets with a surface flux density of 320 mT was placed on the 25-mm-wide thin films and double D-shaped excitation/induction coils were placed on the thin films. A sinusoidal burst pulse current of 0.2 $A_{pp}$ at 60 kHz was input to the excitation coil to generate SH waves with a group velocity of 1670 mm/ms in the CFRP. The similar setting to the transmitter section was used in the receiver section.

In the second experiment, an excitation field parallel to the bias field was applied, as shown in Fig.1(b). The electromagnets, consisting of a U-shaped ferrite with Litz wire wound 52 turns around it, were used. Six electromagnets were placed on the thin film and connected in series in the transmitter section. To provide a bias magnetic field, a DC current of 1.6 A was applied to the electromagnets. Simultaneously, a sinusoidal burst pulse current of 0.2 $A_{pp}$ at 60 kHz was input also, to generate guided waves. In this case, $S_0$-mode Lamb waves with a group velocity of 5500 mm/ms are mainly generated in the CFRP. The receiver section was configured in the same way as the transmitter section.

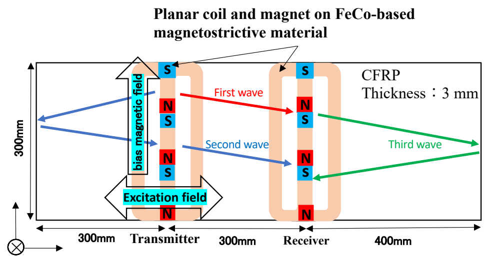
2.3 Experimental results Experimental results are shown in Fig. 2(a) and 2(b), respectively. As shown in Fig. 2(a), the incident SH wave was measured from about 180 μs, and the reflected wave from the left end of the sample was measured from about 530 μs. On the other hand, the small amplitude wave seen from about 55 μs is the $S_0$-mode

Lamb wave.

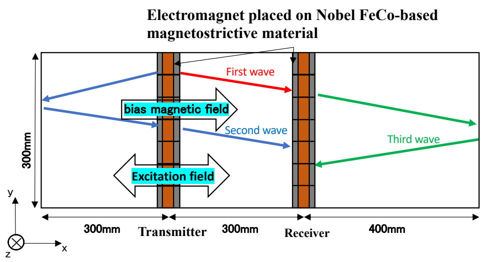
As shown in the Fig. 2(b), the incident wave of the $S_0$-mode Lamb wave was measured from about 55 μs, and the reflected wave from the left end of the sample was measured from about 160 μs with larger amplitudes than the SH waves in Fig. 2(a). The third wave from about 190 μs is larger than the second wave and should be a superposition of $S_0$-mode Lamb wave and the SH wave. A wave with slower frequency than 60 kHz wave seen from about 240 μs should be $A_0$-mode Lamb wave, which is estimated from its propagation group velocity. The $S_0$-mode Lamb waves in Fig. 2(b) shows that the attenuation of the waves with respect to the propagation distance is much smaller than that of the SH waves in Fig. 2(a). The results demonstrated that the Lamb wave is more suitable to inspect a wider area in the CFRP plate.

## 3. Conclusion

In this study, we investigated the application of novel FeCo-based magnetostrictive materials, which has larger magnetostrictive effects than nickel, to expand the measurement range by increasing the sensitivity of the magnetostrictive guided wave inspection technique. As a result, it was shown that $S_0$-mode Lamb waves generated with the novel materials has the potential for inspection over a longer range than the SH waves.

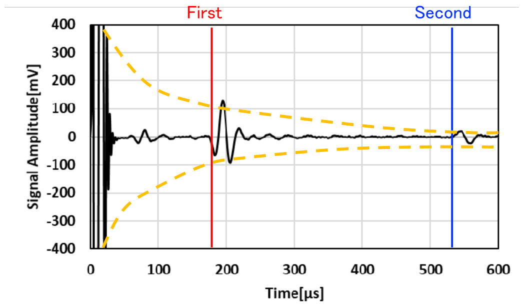



(a)

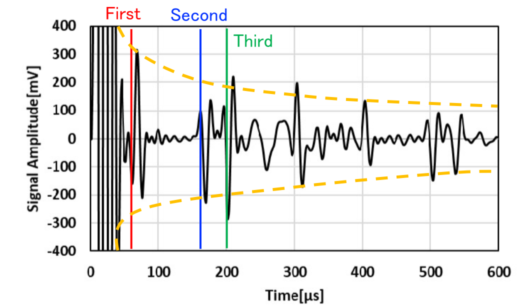



(b)

Fig. 1 Experimental settings.
(a) Excitation field is applied perpendicular to bias field. (b) Excitation field is applied parallel to bias field.




(a)




(b)

Fig. 2 Guided wave measurements
(a) SH waves were the main waves. (b) Lamb waves were the main waves.

## References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