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Development of SV-wave point-focusing electromagnetic acoustic transducer

SV 波点集束型電磁超音波センサの開発

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1. Introduction

For nondestructive testing using acoustic waves, piezoelectric transducers are often used. With piezoelectric transducers, coupling materials are required to transmit acoustic wave from the transducers to the specimens. Waveforms obtained with piezoelectric transducers are then easily affected by amounts of coupling materials and the surface conditions of specimens. In contrast, electromagnetic acoustic transducers (EMATs) are composed of coils and magnets and can excite acoustic waves without using coupling materials, leading to higher reproducibility than conventional piezoelectric transducers. However, lower signal transduction efficiency of EMATs than piezoelectric transducers has been a disadvantage of EMAT. In this study, to solve the disadvantage, a shear vertical (SV)-wave point-focusing EMAT (PF-EMAT) is developed for the first time.

Fundamental concept of the PF-EMAT is based on theory of line-focusing EMAT (LF-EMAT) developed by Ogi *et al*[1]. In the LF-EMAT, SV-waves genertd from several line sources are focused on a focal line in specimen. In this study, using curved meander-line coils, the point focusing is achieved. This improvement increases the signal intensity and makes the point focusing. In addition, we increased the number of turns of the coil in order to increase the intensity of the SV-waves. Thus, the resolution and intensity are improved.

We use a stainless steel as a specimen. It is widely used in many structures, for example, piping in atomic power plants. Application of EMATs to stainless steels is however difficult comparing to aluminum alloys, because in stainless steels acoustic waves are significantly scattered because of coarse grains. This study shows that our PF-EMAT successfully detects slit defects larger than 0.5 mm in a stainlless steel.

2. Experimental Setup

Figure 1 (a) shows driving mechanism of the focusing EMAT. A meander-line coil is located on a specimen surface, and a permanent magnet is put on it. The traction forces are generated by the Lorentz forces excited from the coupling of the static

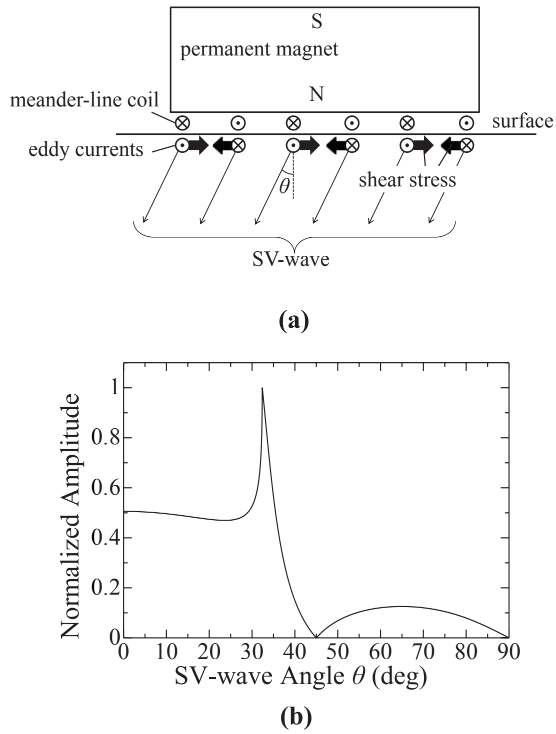

Fig. 1 (a) Driving mechanism of the ordinary meander-line coil EMAT whose segments are located at a regular interval. (b) Directivity of the SV-wave amplitude generated by a single line source in stainless steel.

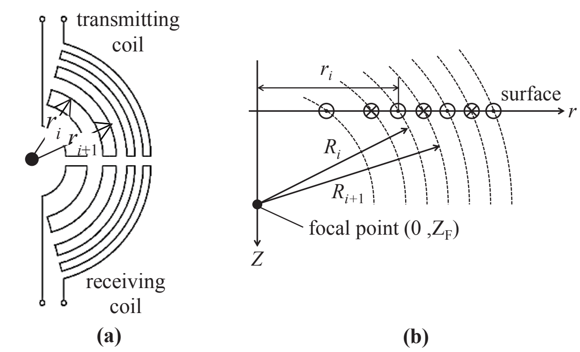

Fig. 2 (a) Layout sketch of curved meander-line coils of PF-EMAT. (b) Schematic explanation for determining the curved meander-line configuration.

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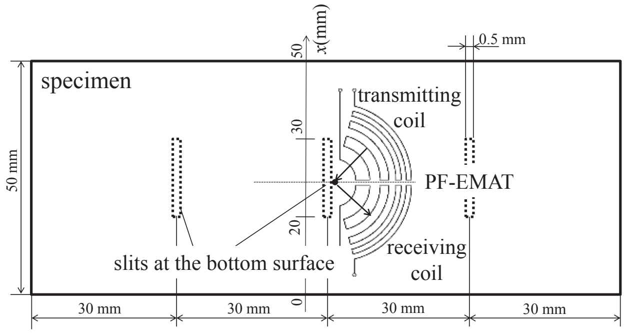

Fig. 3 Experimental setup.

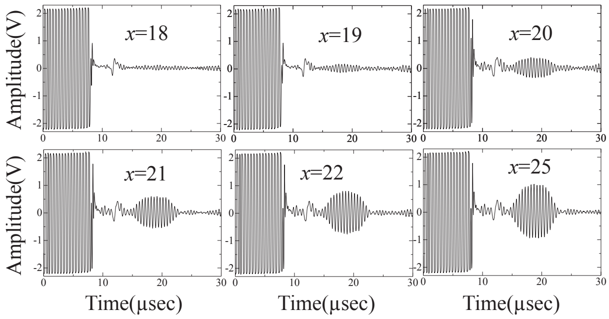

Fig. 4 Received waveforms at x=18-25 mm from the slit defect of 1.5mm depth.

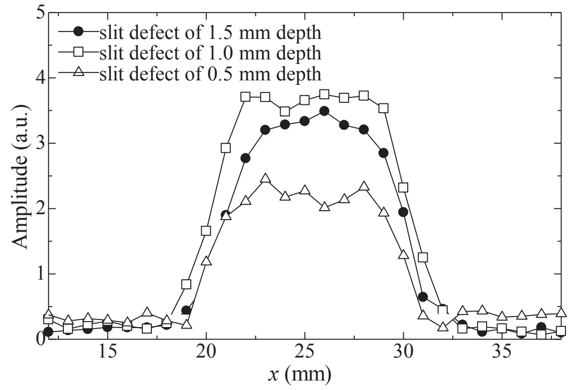

Fig. 5 Amplitudes measured at x=12-38 mm for the three slit defects.

magnetic field and eddy currents. When a single line source is considered, the SV-wave amplitude shows directivity as shown in **Fig. 1 (b)**[2], which is the calculation result for SV-wave propagating in stainless steel; θ denotes the radiation angle of the SV-wave from the normal direction to the surface. The amplitude shows a sharp peak at about θ = 32°, beyond which the amplitude drops. This feature is advantage of the line source for focusing the SV-wave.

Figures 2 (a) and (b) show schematic explanation of relationship between the focal point and configuration of the coil. (0 , Z_F) is the location of the focal point, λ is the wave length of the SV-wave, and r_i is the radius of the ith segment. Once (0 , Z_F) and λ are determined, $r_{(i+1)}$ is determined so that the difference between the propagation paths of the ith and (i+1)th segments is a half wavelength, that is $R_{(i+1)}-R_{(i+1)}= \lambda/2$, in order to make the phases of all the waves equal[1]. In this configuration, the focusing mechanism operates for both excitation and reception. Our PF-EMAT consist of two curved meander-line coils for transmitting and receiving, and the number of turns of the coils is increased in order to enhance the intensity of generated SV-waves.

A stainless steel (SUS304) specimen with a volume of 120×50×20 mm^3 (length×width×thickness) was used. Three slit defects were machined at the bottom surface as shown in **Fig. 3**. Each slit has the same length (0.5 mm) and width (10 mm), but different depth (0.5, 1.0, and 1.5 mm). A measurement system with a gated-amplifier and a superheterodyne spectrometer (RITEC, RAM-10000) was used for driving the PF-EMAT and receiving the signals. The high-power RF bursts were applied to one of the coils. The driving frequency was 2 MHz and the burst duration w as 6 μs. Z_F was 20 mm so that the focal point is located at the bottom surface. The PF-EMAT was placed on the upper surface and moved in the x direction. The PF-EMAT transmitted SV waves, which were reflected by the slit defect, and the the other coil of the PF-EMAT received them. The received signal was sent to the superheterodyne spectrometer to measure the amplitude of the driving-frequency component.

3. Results and Discussion

Figure 4 shows received waveforms at x=18-25 mm from the slit defect of 1.5 mm depth. As the PF-EMAT moved toward the slit, the amplitude of the signal became larger.

Figure 5 shows amplitudes measured at x=12-38 mm for the three slit defects. The PF-EMAT clearly detected all the defects. The amplitude of the signal from the 0.5 mm defect was smaller than those from other defects, but that from the 1.0mm defect was slightly larger than that from the 1.5mm defect. (This reason is unknown at present.) The amplitude profiles exhibit sharp edges at the ends of the defects, confirming that the focal size of the PF-EMAT is small enough to detect the present slit defects. For each slit, the amplitude started to increase at about x=18, arrived at the peak level at about x =22, started to decrease at about x =29 and arrived at noise level at x =32. From these results, the representative length of the focal area of SV-waves generated by PF-EMAT is about 4 mm in the x direction.

References

1. H. Ogi, M. Hirao, and T. Ohtani, IEEE Trans. Ultrason. Ferr. Freq. Cont. **46**, 341 (1999).
2. G. F. Miller and H. Pursey, Proc. R. Soc. London, Ser. A **223**, 521 (1954).