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Detection of cracking near welding of SUS316 pipe by shear-vertical-wave point-focusing-electromagnetic acoustic transducer

SV 波点集束型電磁超音波センサによる SUS316 鋼管の溶接部近傍の割れの検出

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1. Introduction

In nuclear power plants, stainless steel pipes are used for its tolerance to the corrosion. However, welding degrades the corrosion resistance and induces residual stress around welded area, resulting in stress corrosion cracking (SCC) in the heat affected zone (HAZ). The SCC leads to leakage of radioactive materials at worst. It must be detected in the early stage. For detecting SCC on the inner surface of pipes, ultrasonic testing with piezoelectric transducers is generally conducted. In ultrasonic testing, acoustic waves are incident to the cracks obliquely from the outer surface, and acoustic waves reflected from the cracks are received by the same transducer. Piezoelectric transducers require liquid couplant to transmit and receive acoustic waves, and the amplitude of the received signal is affected by the amount of the couplant and the contacting force between the transducer and the specimen surface. These factors lower the reproducibility, and sizing of small cracks is difficult.

For detecting small cracks, we developed a shear-vertical-wave point-focusing-electromagnetic acoustic transducer (SV-wave PF-EMAT)[1]. This is composed of magnets and coils, and the Lorentz forces generated by the interaction between the static magnetic field of the magnets and the eddy currents induced by the coils is the source of the SV waves. The SV-wave PF-EMAT requires no couplant, leading to higher reproducibility than conventional piezoelectric transducers. In conventional EMATs, the signal intensity is usually lower than in piezoelectric transducers, which has been a disadvantage. In the SV-wave PF-EMAT, the signal intensity and spatial resolution are improved by focusing SV waves at a focal point in phase. In this study, we detect artificial cracks near the weld metal using the SV-wave PF-EMAT and demonstrate its crack detectability.

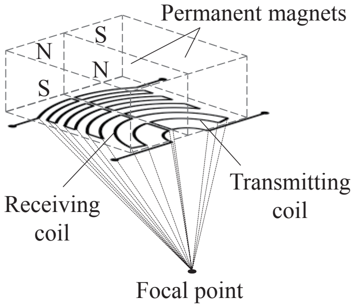

Fig. 1 Layout sketch of SV-wave PF-EMAT for pipe inspection.

2. Experimental setup

Figure 1 shows the layout sketch of the SV-wave PF-EMAT designed in the present study. This is composed of two magnets and two concentric meander-line coils for transmitting and receiving SV waves. The coils are placed on the specimen surface, and the magnets are placed on them. By applying rf bursts to the transmitting coil, the eddy currents are induced on the specimen surface, and the SV waves are excited by the in-plane Lorentz forces. The receiving coil receives the SV waves reflected from the cracks with the reverse mechanism. The amplitude of the SV wave radiated from each line source depends on the direction of propagation[2]. In a stainless steel, it is almost constant in the range 0°<θ<30°, shows a sharp peak (the height is about twice larger) around θ=32°, and becomes nearly zero for θ>32°. The phase remains unchanged at θ≤32°. θ denotes the measured angle from the normal direction to the surface. Thus, the SV wave is suitable for detecting cracks in the particular angler direction. In addition, the SV-wave PF-EMAT focuses SV waves at a focal point in phase, and the signal intensity increases and space resolution becomes finer. The point focusing is achieved by gradually changing the interval of the line sources[1]. Because the Lorentz forces generated by neighboring segments have opposite phases each other, the intervals of the segments are determined so that the phases of all the SV-waves generated by the segments equal at the focal point.

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A specimen cut from a SUS316 pipe of 35 mm thickness and 609.6 mm diameter is used. There is a welded region along the circumferential direction. There are two cracks (Crack 1 and Crack 2) on the inner surface beside the weld metal. They were artificially made using chemicals under bending stress. The width of apertural area is less than 10 µm. They are located at about 8 mm and 2 mm from the edge of the weld metal on the inner surface and their lengths are about 19 mm and 12 mm in the circumferential direction, respectively. Their depths will be known by breaking the specimen.

The concentric meander-line coils have ten line sources, and the shape is designed so that the radiation angle θ varies between 6.5° and 33.9° and the focal point is located on the inner surface. A measurement system with a gated-amplifier and a superheterodyne spectrometer (RITEC, RAM-10000) is used for driving the SV-wave PF-EMAT and receiving the signals. The driving frequency is 2 MHz, and the burst duration is 10 µs.

We measured amplitude profiles along the axial direction for the cracks and flawless area by scanning at 1 mm steps.

3. Results and discussion

Figure 2(a) shows the experimental setup, **Figs. 2(b)**, **(c)** show the typical waveforms obtained from flawless area and Crack 1, and **Figs. 2(d)-(f)** show the amplitude profiles. The horizontal axis, *y*, is the position of the focal point in the axial direction on the inner surface, and the weld metal is located at *y*=299-306 mm (**Fig. 2(a)**). In **Fig. 2(d)**, signals reflected from the welded region were observed at *y*=299-305 mm, but notable signals were not observed in the flawless area. In **Fig. 2(e)**, Crack 1 is located at about *y*=291 mm. Amplitude shows a sharp peak at *y*=292 mm, and it can be distinguished from the signals from the welded region. In **Fig. 2(f)**, Crack 2 is located at about *y*=297 mm. The amplitude profile shows a peak around *y*=297 mm, and it is significantly larger than the signals from the welded region. In addition, the amplitude from the welded region is smaller than that in **Fig. 2(d)**. Possibly, it is because a part of SV waves propagating to the weld region is blocked by Crack 2. These results confirm that the SV-wave PF-EMAT is capable of detecting cracks even near the welded region in SUS316 pipes and it has potential to detect SCCs in nuclear power plants.

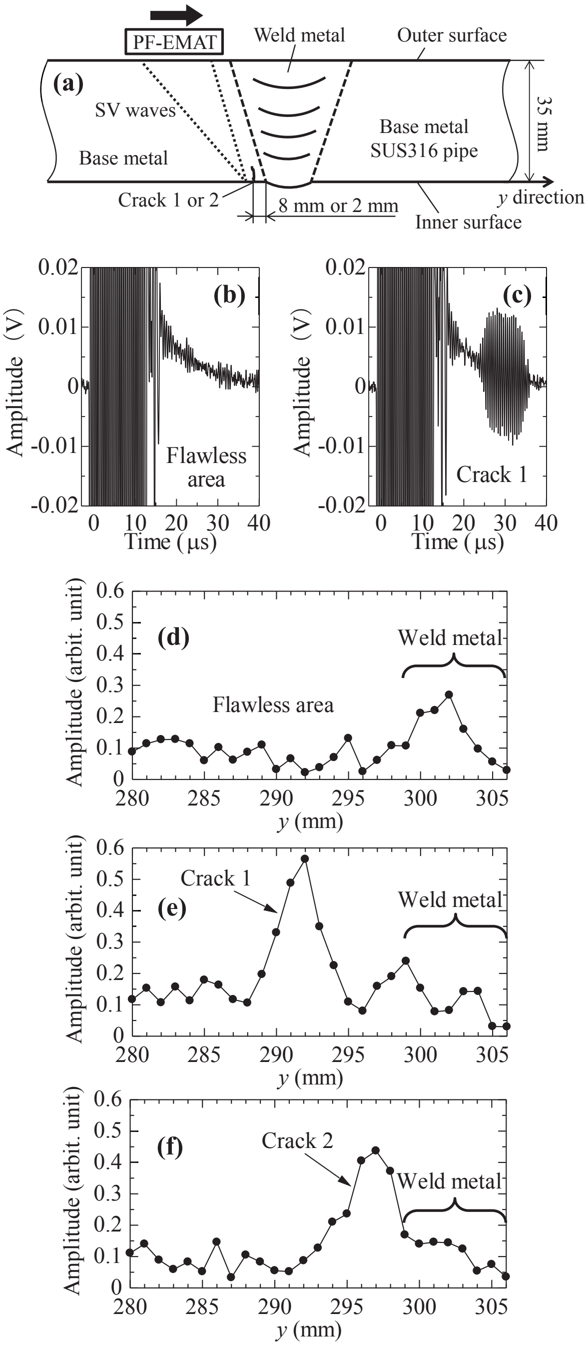

Fig. 2(a) Experimental setup. (b), (c) Typical waveforms obtained from flawless area and Crack1, respectively. (d)-(f) Amplitude profiles measured at *y*=280-306 mm for flawless area, Crack 1, and Crack 2.

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References

1. T. Takishita, K. Ashida, N. Nakamura, H. Ogi, and M. Hirao, Jpn. J. Appl. Phys. **54**, 07HC04 (2015).
2. G. F. Miller and H. Pursey, Proc. R. Soc. London, Ser. A **223**, 521 (1954).
3. H. Ogi, M. Hirao, and T. Ohtani, IEEE Trans. Ultrason. Ferr. Freq. Cont. **46**, 341 (1999).