1P2-6

Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)
16-18 November, 2016

A highly sensitive Lamb wave transducer by immersion method with natural rubber insulator

天然ゴム減衰材を利用した水浸法による高感度 Lamb 波用トランスデューサ

Satoshi Obata[1‡], Masashi Ishikawa[1] and Hideo Nishino[1] ([1]Advanced Tech. and Sci. Tokushima Univ.)
小畑　智 [1‡], 石川真志 [1], 西野　秀郎 [1] ([1] 徳大院　理工学研究部)

1. Introduction

The Lamb wave [1] inspection is a useful and efficient technique for nondestructive testing of plate specimens. In 1962, Several methods [2] have already been investigated to generate the Lamb wave and the Rayleigh wave. The wedge method or so-called coincidence method is widely used for the generations of them. In the method, longitudinal waves propagating in wedge material transforms into the Lamb waves in plate on which the wedge is mounted. The immersion method is one of the alternative wedge methods, which uses water couplant as a wedge material. Low longitudinal wave velocity, low attenuation coefficient, and variable incident angle are main advantages of the immersion method comparing to the solid-wedge method. In the immersion method, however, the reverberated longitudinal waves in water couplant become spurious baseline signals that distort the defect signal because of the low attenuation coefficient of water. In this paper, highly sensitive Lamb wave transducer was proposed to reduce the spurious baseline signals using the natural rubber insulator located in the water couplant.

2. Lamb wave transducer and baseline reduction

Figure 1 shows the Lamb wave transducer manufactured. A longitudinal wave transducer was placed into the acrylic water bath. According to the Snell's law, the incident angle of the longitudinal wave transducer was set to the critical angle for the Lamb wave generation. A natural rubber block was employed in front of the transducer as an insulator for reducing the reverberated spurious longitudinal waves in the water bath. The natural rubber is suitable to an insulator in water because the attenuation coefficient is extremely large and the other acoustical parameters (c_l = 1475 ± 2 m/s, c_t = 83 ± 2 m/s, ρ = 1550 ± 10 kg/m^3) of it are very similar to those of water. Theoretical reflection coefficient at interface from water into the natural rubber as a function of incident angle normal to the natural rubber surface is shown in **Fig. 2**. The reflection coefficient takes almost zero when the incident angle is around 80°. This means that the spurious longitudinal wave packets in water are reduced effectively when the incident angle to the natural rubber surface is 80°.

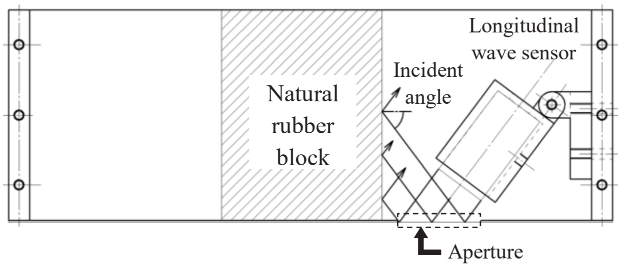

Fig. 1 Illustration of the Lamb wave transducer

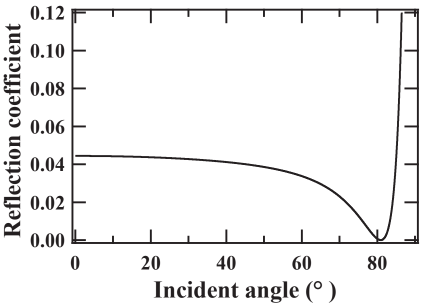

Fig. 2 Theoretical reflection coefficient from water to the natural rubber surface as a function of incident angle

3. Experiments and results

Experimental apparatus was shown in **Fig. 3**. A 2-mm-thick aluminum plate was used. 750 kHz and 10 cycle tone burst signals were used in the verifications. The critical angle for the Lamb wave generation was set experimentally around 37° so as to take the maximum amplitude. The incident angle of the longitudinal wave from water to the rubber surface was varied from 20° to 85° at 5° intervals.

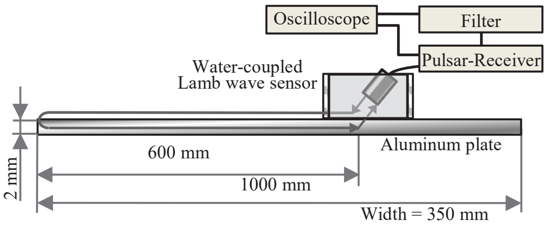

Fig. 3 Illustration of experimental setup

---

hidero.nishino@tokushima-u.ac.jp

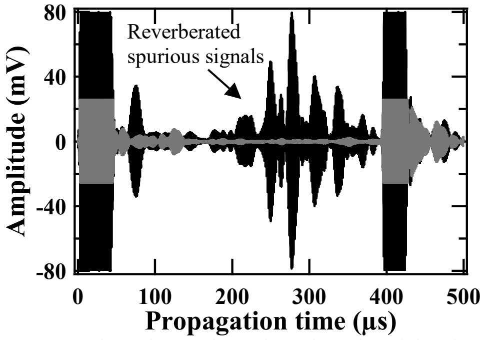

Fig. 4 The time domain signal with the natural rubber insulator (gray) and without any insulator (black) in the water bath.

Figure 4 shows the time domain signal without the natural rubber. As well as edge-reflected signal, many spurious signals were found due to the reverberated longitudinal waves in water. Here, the (edge reflected) signal to spurious signal ratio (S/Ss) was 16 ± 5. **Figure 5** shows the variation of time domain signals for the different incident angles. A propagation time until 50 μs is the dead zone. Reflected signals from the natural rubber surface can be observed in a propagation time from 50 to 150 μs, which are a part of the very small remainder of the penetrated wave at the water-rubber interface. In **Fig. 6**, the maximum spurious signal amplitude observed in a propagation time from 50 to 150 μs was plotted as a function of the incident angle normal to the rubber surface. These relations were very similar to the theoretical reflection coefficient as shown in Fig. 2. It can be confirmed that the maximum spurious signal takes the minimum at the incident angle of 80°. Analogously, Figure 2 shows the minimum at around 80°. **Figure 7** shows the S/Ss during a propagation time between 150 and 400 μs as a function of incident angle normal to the natural rubber surface. Regardless of the incident angle, the S/Ss was around 500. It was 16 while the natural rubber block was not installed.

4. Conclusion

A highly sensitive Lamb wave transducer by immersion method with a natural rubber insulator was proposed and evaluated. It was confirmed that the baseline spurious signals were suppressed to control optimally the incident angle normal to the natural rubber surface. The mechanism of the suppression of the spurious signal was discussed with the theoretical reflection coefficient at the interface between water and the natural rubber. It was confirmed that the lowest spurious signal was obtained while the optimal incident angle estimated theoretically was employed. Optimal incident angle of the signal to spurious signal ratio (S/Ss) was experimentally obtained around 500.

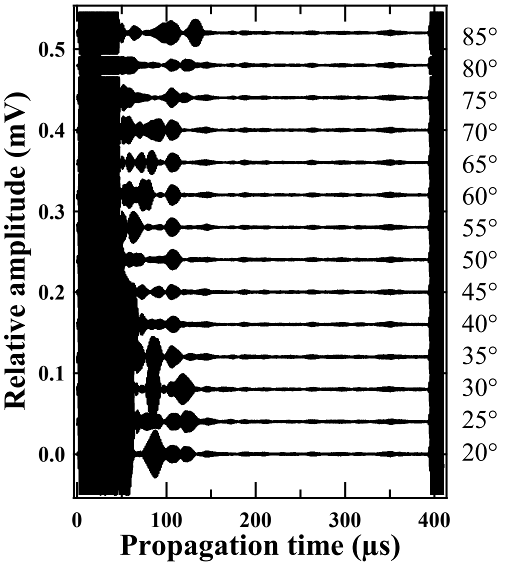

Fig. 5 Variation of the time domain signals for different incident angle normal to the natural rubber (enhanced in vertical axis)

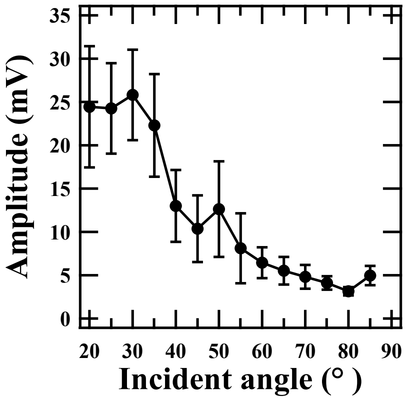

Fig. 6 the maximum spurious signal amplitude in a propagation time from 50 to 150 μs

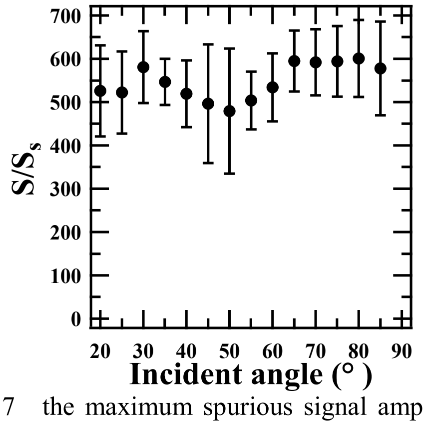

Fig. 7 the maximum spurious signal amplitude in a propagation time from 150 to 400 μs

Acknowledgment

This work was supported by a grant from the Iron and Steel Institute of Japan (ISIJ).

References

1. I. A. Viktorov, Rayleigh and Lamb waves, (Plenum, New York 1967).
2. I. A. Viktorov, Soviet Phy. Acoust. 7 (1962) 236.