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Enhance Amplitude of Incident Wave by Using Acoustic Matching Wedge for Subharmonic Ultrasound Measurement

サブハーモニック超音波計測のための音響整合くさびによる入射波の大振幅化

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1. Introduction

Recently, nonlinear ultrasound measurement has become an effectual means to detect and assess closed cracks since the basical study reported three decades ago [1]. The Subharmonic Phased Array for Crack Evaluation (SPACE) measurement, which is an imaging system of the subharmonic ultrasound generation at crack, have been reported for several years [2]. Although SPACE measurement have a better selectivity for closed cracks than any other nonlinear ultrasound measurements, the subhrarmonics appear only when the amplitude of incident wave is larger than a certain threshold [3].

On the other hand, resin materials are widely used for angle beam wedge in ultrasonic testing, because their acoustic impedances are similar to that of contact medium, i.e. ultrasonic couplants. However, reflected enegy of the transmission wave in the pathway from transducer to crack is not negligible because incident wave has to pass through two boundaries, i.e. interfaces between probe – wedge and wedge – specimen. When UT applied to steels, these energy losses are large due to very low acoustic impedance of resin wedge. On the small roughness surface, we consider the effect of contact medium is less affected, then acoustic impedance of the wedge should be close to that of probe and specimen rather than contact medium.

In this study, we developed a new wedge using PZT materials to match well the acoustic impedance to that of steels. Here we report a efficacy of the novel wedge compared with conventional wedge.

2. Experimental details

We prepared the transducers which have a faceplate of pure aluminum (Al) material with a thickness of 0.1 mm. Also, we prepared two kinds of wedge, conventional and new one, i.e. resin type and ceramics type. Resin type is made of polyimide SX-200 (Suzuko, Japan). Ceramics type is made of PZT M-6 which is commercially available from Fuji Ceramics Corporation, Japan.

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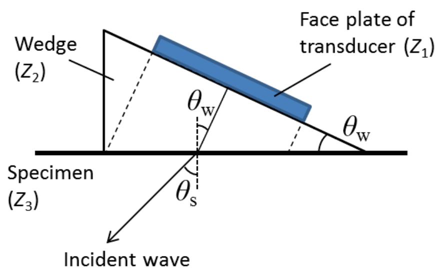

Fig. 1 Pathway of longitudinal wave through a plane interface between wedge and specimen.

Fig.1 shows the pathway of longitudinal wave transmitted into a specimen through a wedge. The incident wave was refracted at the interface between wedge and specimen with a refract angle θ_s. Incident angle θ_w, which is same as elevation angle of wedge, was determined from sound speeds of each material. When a plane wave travels through two interfaces between three media like as **Fig.1**, the transmission coefficient (τ) of sound pressure is expressed as follow equation (1).

$$\tau = \frac{2Z_2}{Z_1 + Z_2} \cdot \frac{2Z_3 \cos\theta_W}{Z_2 \cos\theta_S + Z_3 \cos\theta_W} \qquad (1)$$

Table I　Acoustic properties of the materials.

	Density [kg/m^3]	Sound speed [m/s]	Acoustic impedance [10^3 kg/m^{2}s]
	ρ	***c***	***ρc***
Al	2.7	6260	16.9
SX-200	1.4	2731*	3.8
PZT (M-6)	6.9	4131*	28.5
SUS 304	7.9	5790	45.7

*measured by immersion testing

Acoustic impedances Z_1 to Z_3 of materials are defined as the product of their density and sound speed. **Table I** shows the acoustic properties of the materials which compose faceplate of the transducer, wedge and specimen. In this case, we set refract angle θ_s as 45°, then elevation angles of the each wedge were decided as 19° of resin type, and 30° of ceramics type, respectively. According to equation (1), the transmission coefficients are calculated as 0.69 with resin type wedge (τ_r), and 1.65 with ceramics type wedge (τ_c). Then, about 2.4 times improvement in amplitude of the incident wave is expected.

To measure accurate displacement waveform of the generated ultrasound depend on wedge, we constructed an experimental set up as shown in **Fig.2**. In consideration of 45° oblique incidence to cracks, we prepared an angle-cut sample to evaluate waveform just before reaching cracks. The angle-cut sample, which is made of SUS304 stainless steel, was fabricated by removing triangular from rectangular column. The cut surface was tilted at angle of 45° toward the upper surface. The sample was made to thickness of 40 mm with a uniform width of 40 mm.

The transducer contained a square piezoelectric element of 10 x 10 mm^2 and thickness of 0.4 mm, with a central frequency of 5 MHz. The aluminum faceplate of the transducer was bonded to a wedge, which was contacted with upper surface of the sample by using ultrasonic couplant. This transducer was driven with a high voltage pulser (Japan Probe). Here the wave number was set 3-cycle and the tone burst of 5-MHz longitudinal waves was input. The displacement amplitude on the tilted surface of the sample was calculated from receiving signal of peak-to-peak (p–p) measured by a laser vibrometer (Polytec, OFV-505).

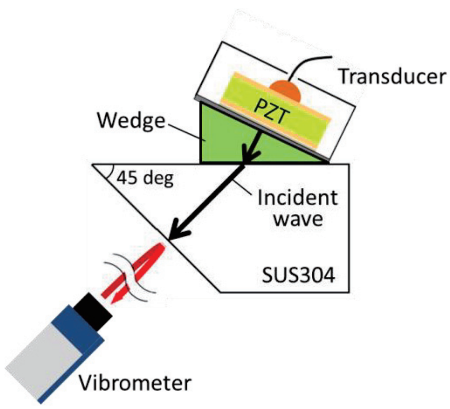

Fig. 2 Experimental set up to measure displacement of incident wave by using a laser vibrometer.

3. Results and discussion

Figs. 3(a) and **3(b)** show measuring results of waveform of displacement on the tilted surface of the sample. In **Fig.3(a)**, the resin wedge was applied. In **Fig.3(b)**, the ceramics wedge was applied. The setting voltage was set to 400 V. From the results, the displacement measured with ceramics wedge was about twice greater than that with resin wedge. This value was a little bit lower than expected value calculated by using equation (1) because the attenuation factors of materials were excluded.

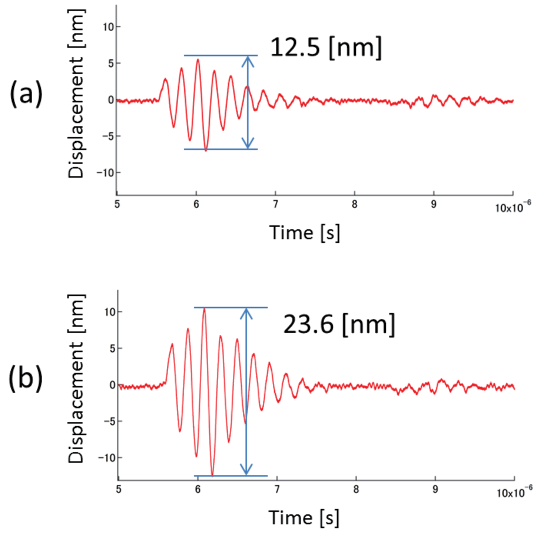

Fig. 3 Waveform of displacement of ultrasound measured with resin wedge (a), with ceramics wedge (b).

4. Conclusions

In this study, we proposed a new wedge using PZT material for matching in acoustic impedance between wedge and specimen to enhance amplitude of the incident wave. Since we observed increasing displacement by using new wedge according to improving transmission efficiency, discussed concept will be available. Further confirmation of attenuation factors in each material should be considered. In future, a dedicated pulser producing larger current must be required to apply high efficient element of transducer.

Acknowledgment

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