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Consideration for Incident Angle in Aluminum Plate by Non Contact Air Coupled Ultrasonic Testing

非接触･空中伝搬超音波法によるアルミニウム平板の入射角の検討

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1. Introduction

We have developed non contact air coupled ultrasonic testing, here after called NAUT.

In NAUT the incident angle is very important, so we considered the condition of the maximum transmission coefficient about guided wave relating the incident angle. We experimented to obtain the maximum wave and then calculated the condition. As the result, the experiment & calculation is in good agreement. When the defect is in specimen propagating the different mode, the amplitude of transmission wave changes by the mode.

2. Experiment

The test specimens are aluminum plates being 0.3 to 10mm thick and 100mm wide、300mm long. Probes are 800 KHz & 400 KHz, the element size: 10×20mm. Ultrasonic pulser & receiver is JPR-10CN by squire burst waves driving.Fig.1 shows one side transmission method.

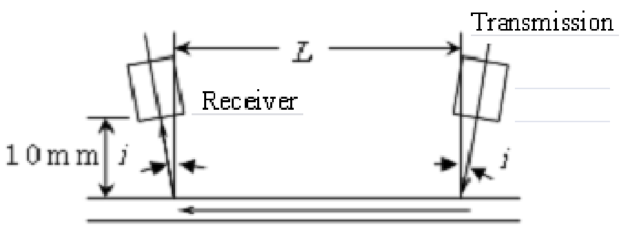


Fig.1 one side transmission method

3. Theory

The transmission coefficient T of the guided wave in a plate is calculated in the following formulas.[1)]

$$T=\frac{4N^2}{4M^2+(N^2-M^2+1)} \quad \text{---------------------- (1)}$$

Where

$$N=\frac{Z_l cos^2 2\theta_l}{Z sin\ k_{ly}d}+\frac{Z_t sin^2\ 2\theta_t}{Z sin\ k_{ty}d}\ 、$$

$$M=\frac{Z_l cos^2 2\theta_l}{Z tan k_{ly}d}+\frac{Z_t sin^2 2\theta_t}{Z tan k_{ty}d} \quad \text{--------------- (2)}$$

$$Z=\frac{\rho v}{cos i}\ 、\ Z_l=\frac{\rho_l v_l}{cos\theta_l}\ 、\ Z_t=\frac{\rho_l v_t}{cos\theta_t}\ 、$$

$$k_{ly}=\frac{\omega}{v_l}cos\theta_l\ 、\quad k_{ty}=\frac{\omega}{v_t}cos\theta_t \quad \text{---------- (3)}$$

$$sin\theta_l=\frac{v_l}{v}sin\ i、sin\theta_t=\frac{v_t}{v}sin\ i \quad \text{-----------------(4)}$$

V: velocity in air、v_l、v_t:that of longitudinal & shear waves in plate,ρ: air density, ρ_l:density in plate、d: plate thickness, i: incident angle in air, θ_l、θ_t:the reflected angle in plate, k_{ly} ,k_{ty}:element of thickness direction for longitudinal & shear waves in plate、 Z, Z_l、 Z_t :acoustic impedance in considering incident angle, ω :ultrasonic angular frequency

4. Comparison Between Theory & Experiment

Fig.2 shows the relationship between the incident angle & fd causing maximum transmission coefficient. The mark of ●&▲ shows A0 mode and ■ for S0 mode of experimental result.

The solid line in Fig.2 is the calculated value by formulas (1)～(4). According to Fig.2 the experimental result & calculated value are in good agreement.

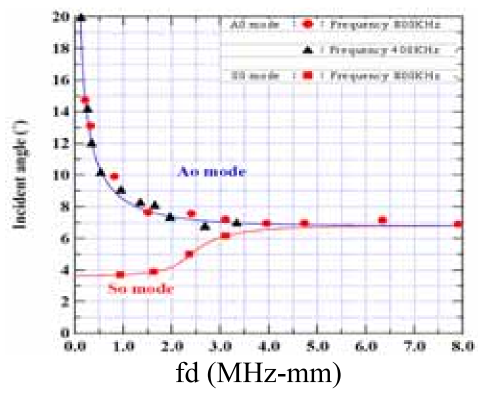
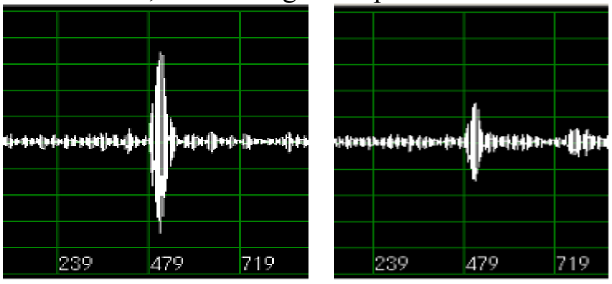


Fig.2 the relationship between fd （frequency ×thickness） & incident angle

5. Propagating Mode and Transmission Waves

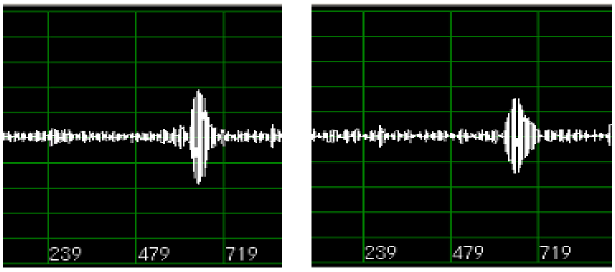
The amplitude of guided transmission wave is different in propagating mode when there is defect in plate, so we considered the relationship between the experiment result and calculated value by experiment and simulation.

Fig.3 & Fig.4 show the amplitude difference of transmission wave in no defect and defect part (slit part). The slit dimension is 1mm and 2mm deep, 0.5mm wide, 20mm long for experiment.



(a) sound part (no defect) (b) slit part

Fig.3 transmission wave of A0 mode



(a) sound part (no defect) (b) slit part

Fig.4 transmission wave of S0 mode

The transmission wave amplitude on A0 mode decreases by defect but the transmission wave amplitude on S0 mode does not change so much in comparing with A0 mode. Fig.5 shows the propagating A0 mode in aluminum plate in 55μs

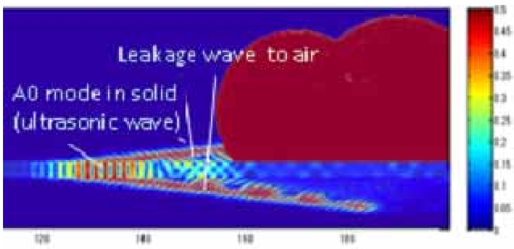


Fig.5 propagating A0 mode in 55us after transmission

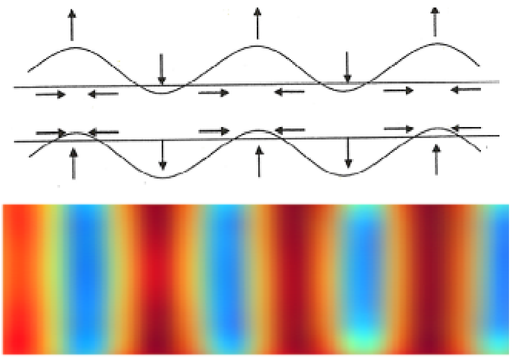


Fig.6 the A0 mode propagation

after ultrasonic transmission[2]. Fig. 6 & 7 show the A0 mode propagation like stripes. Fig.8 shows the S0 mode propagation like a checkered pattern.

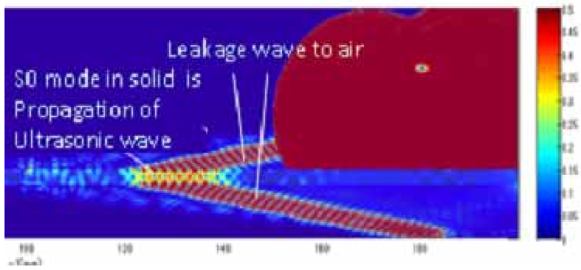


Fig.7 the propagating S0 mode in aluminum plate

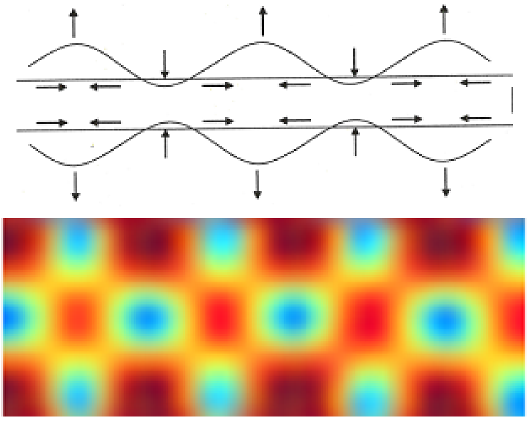


Fig.8 the S0 mode proparation

6. Conclusion

The relationship between fd (product of frequency and thickness) & the incident angle was obtained by non contact air coupled ultrasonic test.

We compared the experiment and calculation result in the incident angle, we obtained the following result.

1) The incident angle obtained in experiment was good agreement in calculation.
2) In A0 mode the amplitude of the transmission wave decreases in defect part, but it in S0 mode does not change so much like A0 mode.
3) The experimental result of propagation is good agreement in the result of simulation.

Reference

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