Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 409-410
20-22 November, 2013

Development and Recent Application of Non Contact Air Coupled Ultrasonic Testing with One Side Access

片面型非接触・空中伝搬超音波検査法の開発と最近の応用

Masakazu Takahashi[1], Yukio Ogura[1], Hideo Nishino[2],Kazuyuki Nakahata[3],
([1]Japan Probe Co. Ltd; [2]Inst. Tech. & Sci., The Univ. of Tokushima, [3] Ehime University,
高橋雅和[1],小倉幸夫[1],西野秀郎[2],中畑和之[3] ([1]ジャパンプローブ㈱, [2]徳島大院, [3]愛媛大学)

1. Introduction

We have developed non contact air coupled ultrasonic testing(NAUT) by one side access with the ultra high power square burst wave pulser and receiver, the pre-amplifier and high sensitive air probes. This paper describes detection of defect in metal by NAUT: V transmission method and Tandem method. And it also describes the applications of the defect detection in metal by guided waves.

2. One side surface V Transmission method

Fig.1 shows one side surface transmission method. Fig.2 shows NAUT21 and high speed scanner.

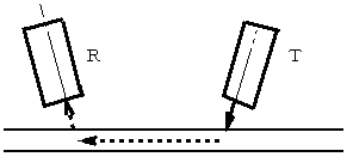


Fig.1 one side transmission method

Fig.2 NAUT21 and High Speed Scanner

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,

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

$$Z=\frac{\rho v}{\cos i},\ Z_l=\frac{\rho v_l}{\cos\theta_l},\ Z_t=\frac{\rho v_t}{\cos\theta_t},$$
$$k_{ly}=\frac{\omega}{v_l}\cos\theta_l,\ k_{ty}=\frac{\omega}{v_t}\cos\theta_t \quad \text{----------(3)}$$

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

V: velocity in air、v_l、v_t:that of longitudinal & shear waves in plate,ρ: air density, ρ_1: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.3 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.3 is the calculated value by formulas (1) ～ (4). According to Fig.3 the experimental result & calculated value are in good agreement.

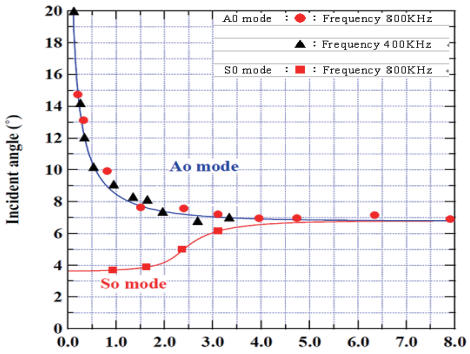
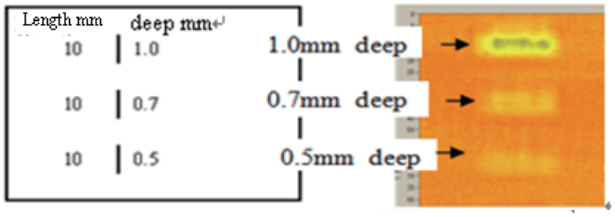


Fig.3 The relationship between fd （frequency ×thickness）& incident angle

5. Application

5. 1 Example of application for surface defect in steel plate [1),]

Fig.4 shows the application of detecting surface opening crack in steel plate. The pate is 15mm thick, the surface opening crack is 0.5mm to 1.0mm deep, 0.5mm wide and 10mm long. The incident angle is 7.0° Fig.4(b) shows clear indication of 0.5mm～1.0mm deep crack. Finite integral method is used for



(a) Test specimen (b) Image pattern

Fig.4 Application of opening crack in steel plate

confirmation of this phenomenon[2]. Surface opening defect is 1mm deep & 0.25mm wide in 15mm thick plate. Frequency is 800KHz , probe distance is 40mm. Fig. 5 shows propagation simulation in transmission and receiving in air. We can observe the leakage wave to air & propagation in steel plate. Fig.6 shows the receiving transmission wave, It is clear that no defect part makes a bigger wave than the defect part of 1mm deep defect.

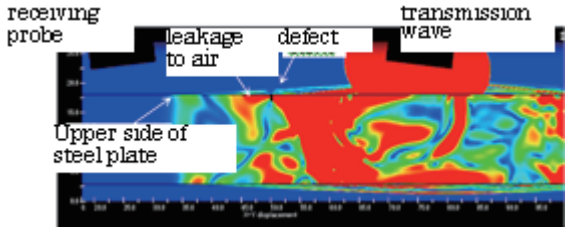


Fig.5 Propagation simulation in transmission and receiving in air

The experiment is good agreement with calculation.

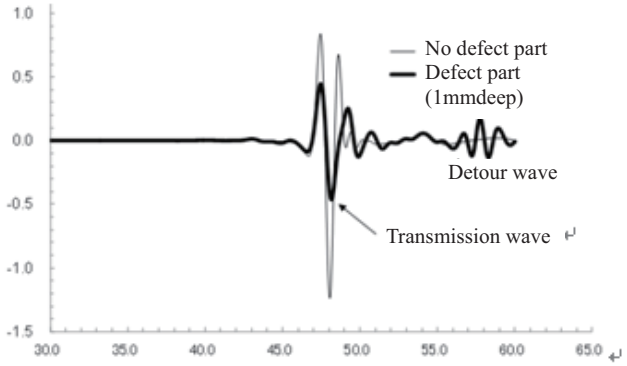
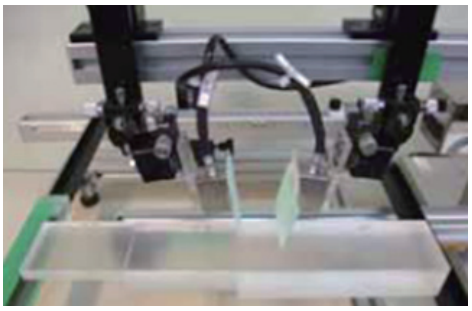


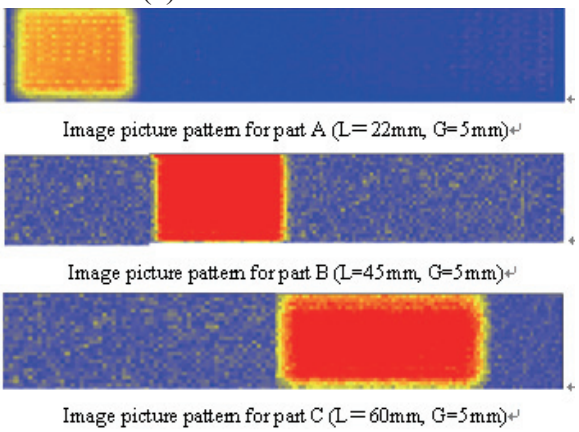
Fig.6 Comparison between no defect part and defect part

5.2 Application of Acrylic plate

We tried the image pattern picture of acrylic step plate;10mm thick, 20mm thick & 30mm thick. Fig.7 shows test method & image pattern picture.



(a) test method



(b) Example of image pattern picture

Fig.7 Test method & image pattern picture

6. Conclusion

We have developed Non Contact Air Coupled Ultrasonic Testing: NAUT by one side access, and succeeded in image pattern picture in metal, aluminum plate. We have obtained the following result.

(1) It is available for applying to detect defect in aluminum plate and metal.
(2) One side access transmission method is not limited like both side access transmission method.
(3) The information of depth direction is obtained in varying the probe distance.

Reference

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(2) Kazuyuki Nakahata, Junichi Tokunaga, Soichi Hirose : Wave propagation simulation in image base & application of ultrasonic testing model,NDI,Vol.59,No.5,PP,231 -238,(2010)