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Development of Non Contact Air Coupled Ultrasonic Testing for Large Structure
空中超音波を用いた大型構造物の非接触検査装置の開発

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1. Introduction

The advantages of air coupled ultrasonic testing are non-contact, non-immersion, and can achieve completely non-destructive testing in addition to the capability of rapid online scanning, which make it wide potential application in non-destructive and insitu-cracks detection for large structures in engineering constructions, wind power, Aeronautics and Astronautics field. It is impossible to detect the reflected and scattered wave of the internal defects by employing air coupled pulse-echo response mainly because most of the acoustic wave has been reflected due to the large difference of acoustic impedance between air and testing object. It is necessary to amplify 100 dB for the receiving signal for identifying the acoustic wave. Another reason is coverage of the reflected and scattered wave by the wave reflected from surface and it is difficult for low frequency probes to detect due to the long vibrating time [1].In 2011, Takahashi, et al [2] has developed the air coupled ultrasonic testing by transmission method, but it is just applicable for small structures. Here, we consider the possibility of V transmission method to solve the problem. The transmitting wave propagates through air and penetrate into the object and be reflected. The receiving probe is set at the same side to receive this reflected signal.

This paper describes the developed system for measuring acoustic velocity and detecting internal defects by employing the V transmission method. Firstly, we introduce the basic working principle of the V transmission method and the components of the developed system and their functions. Then, we measured the propagating velocity in the testing block. The detection and imaging of the artificial crack was also achieved. The measured results demonstrate the effectiveness and practical application of the V transmission method for air coupled ultrasonic testing system with large structures.

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2. V-Transmission method

The working principle is shown in Fig.1. The transmitting distance in the testing block can be calculated by

$$L_s = 2h / \cos\theta_r \quad (1)$$

h is the thickness of the object, and θ_r can be given according to Snell's law,

$$\sin\theta_i / V_a = \sin\theta_r / V_s \quad (2)$$

V_a and V_s are the acoustic wave velocity in the air and the velocity of the shear or longitudinal wave in the testing block, and θ_i is the incident angle. As is obvious that,

$$T = T_s + T_a, \quad T_a = L_a / V_a, \quad T = L_s / V_s \quad (3)$$

T is the transmitting time and can be measured, L_a and L_s are the transmitting distance in the air and in the testing object. Thus, the velocity can be determined by the following equation

$$V_s = 2h / \cos(\theta_r (T - T_a)) \quad (4)$$

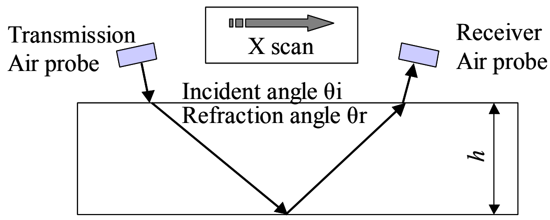


Fig.1 V-Transmission method

3. Development of Image Equipment for NAUT

Fig.2 shows the non-contact air coupled ultrasonic detecting system for V transmission method. It is composed by computer, high-power ultrasonic pulser and receiver, high-speed encode and ultra-wideband air coupled probes and automatic scanner, control motor and memory module. The system can also realize the pulse compression and multi-path routing average.

Two scanning modes can be achieved: B mode to measure the velocity and C scanning for imaging the defects. For B mode, the transmission probe is fixed and the receiving probe can be moved along

X-axis. The acoustic wave velocity in the block, can be averaged by changing the propagating distance. For C mode, the two probes move along X-axis simultaneously to image the defects in the subjects.

Meanwhile, the system can realize the detecting of complex structure by changing different scanning instruments.

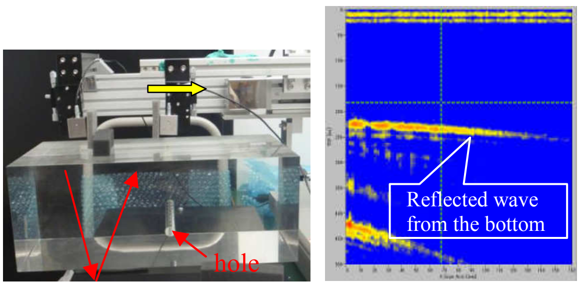
Fig.2 System of non contact air coupled ultrasonic inspection (V-Transmission method)

4. Example and results

4.1 Measurement of velocity (B scanning)

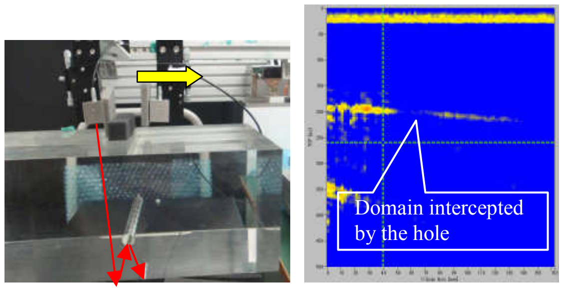
Fig.3 (a) shows the designed experiment to demonstrate the effectiveness of measuring the velocity. The testing object is Acrylic block, whose size is 200mm×400mm×150mm. There is a hole of φ14 below the up-surface of the subject. The transmission probe was fixed in the left side, whose working probe is 120 kHz. The receiving probe is set in the right side, whose working frequency is selected to be 100 kHz considering the damping in the material. Moving the right probe along X-axis to scan the section without the hole, and the pitch is 1 mm. The scanning result is shown in Fig.3 (b). The yellow part of the top is the imaging of the surface reflected wave. The middle part is the reflected wave from the bottom of the subject. The delay time of the pulse is due to the enlarged distance of the two probes.

The same scanning method was applied to the section with the hole to further verify the accuracy of reflected wave from the bottom. The two probes were set to two sides of the hole, as shown in Fig.4 (a) and the scanning result was shown in Fig.4 (b). It was shown that there is a discontinuous region caused by the blocking of the reflected wave by the hole. Other parts are exactly the same. The velocity of the subject can be calculated by the propagating path of the wave.



(a) (b)

Fig.3 Image of Acrylic block by B-scan

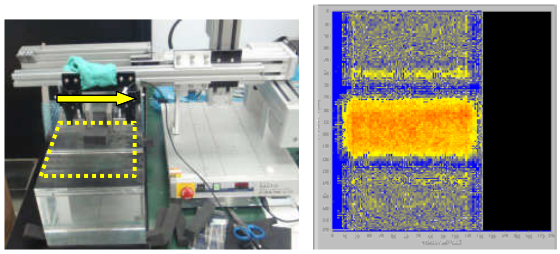


(a) (b)

Fig.4 Image of Acrylic block by C-scan

4.2 Imaging of the defect (C scanning)

The detection and imaging of the internal defects is shown in Fig.5 (a), the testing block is the same as in Section 4.1. The distance between the two probes keeps constant. The V transmission filed is in the dotted square and the scanning step is 1 mm. The experimental results are shown in Fig.5 (b). The horizontal axis is X direction and vertical axis is Y direction. The density of the yellow dot indicates the magnitude of the acoustic. As shown in the figure, the middle part corresponds to the reflected wave from the artificial hole and the color is deeper yellow. The top and bottom part correspond to the acoustic wave reflected from the surface of the block, and the color is lighter compared to that of the middle part. The right and left parts are also blue due to weakness of the reflected wave due to the V method.



(a) (b)

Fig.5 Image of Acrylic block with hole by C-scan

5. Conclusion

We have developed the V transmission system using for online scanning, insitu-defects testing and automatic detection. The system consists of ultra-high power ultrasonic air coupled probes with the function of damping, pre-amplifier with large S/N. It obtains the pulse compression and multi-path routing average and enhances the S/N to a maximum value. It is potential application in non-destructive and insitu-cracks detection for large structures in engineering constructions, wind power, Aeronautics and Astronautics field.

Acknowledgment

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References

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