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Defect detection inside billet by ultrasonic transmission method using phased array technique

フェイズドアレイ技術を用いた超音波透過法による角鋼片内部欠陥検出

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1. Introduction

As a inspection method for a billet, which is a semi-finished products of steel products, we have proposed ultrasonic transmission method using time-of-flight (TOF) of longtitudinal wave[1]. This method can detect defects near the surface of a billet, which is difficult to detect by conventional pulse echo method. Although larger intensity of the received signal can be obtained by using transmission method than by pulse ehcho method[2], there are still difficultied in inspection of high-attenuation and large size billet.

Therefore, we propose defect detection inside billet by ultrasonic transmission method using phased array technique. Although phased array technique has been researched and adopted for pulse echo method[3], few studies adopted phased array technique to transmission method. In this study, the validity of proposed method using phased array technique is evaluated by wave propagation simulations.

2. Principle of defect detection

Figure 1 shows a scheme of defect detection by transmission method using phased array technique. Ultrasonic signals are projected to a billet from transmitter arrays and received at opposite side by receiver arrays. Focused ultrasonic beam is transmitted by transmitter arrays setting time-delays based on time of flight from the focal spot. If there is a defect on the ultrasonic propagation path, amplitude and phase are affected. The deviation of the amplitude and the phase are obtained by measuring $m(t)$ and $r(t)$. $m(t)$ and $r(t)$ are measured at measurement and reference plane with no defects, and obtained by summing up received signals of the received arrays at each plane, respectively. As shown in right side of Fig. 1, the peak value of amplitudes A_m and A_r, at $r(t)$ and $m(t)$, respectively are obtained. Shift in phase $\Delta\tau$ are obtained by cross correlation function between $r(t)$ and $m(t)$ calculating deviation of the peak position

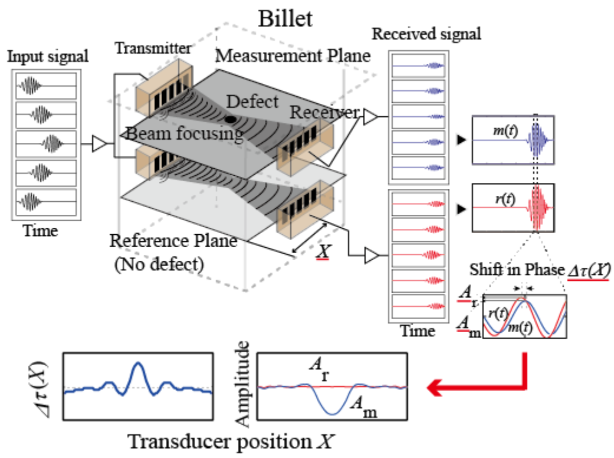

Fig. 1 Outline of defect detection inside billet by transmission method using phased array technique.

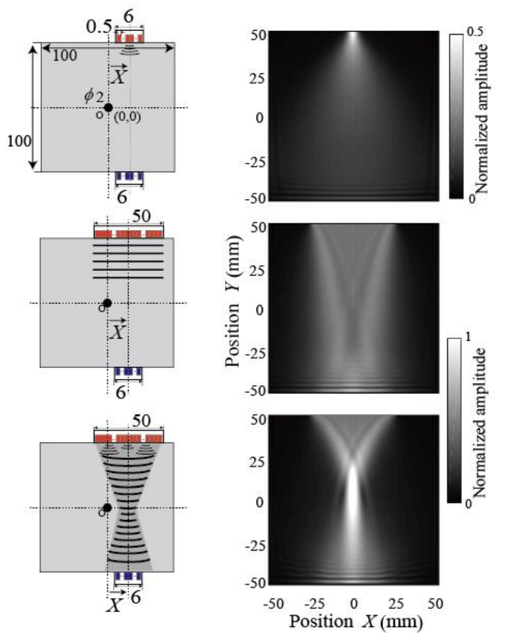

Fig. 2 Simulation conditions and power of particle velocity at each methods.

of the function from that of autocorrelation. Defects are detected by the relationship between transducers position X, maximum amplitudes A_m, A_r, and $\Delta\tau$, shown in below of Fig. 1.

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3. Numerical simulation

To simulate the wave propagation for effect detection by the proposed method, two-dimensional finite-difference time-domain (FDTD) method for elastic wave in solid was employed[4)]. In this simulation, isotropic elastic material was assumed. The left side of **Fig. 2** shows the conditions of simulations. Tested billet was assumed to be steel which has cross section of 100 × 100 mm^2, the density was 7,700 kg/m^3, and the velocities of longitudinal wave and shear wave were 5,950 and 3,240 (m/s), respectively. The surface and a defect of a billet was assumed to be a free boundary, on which stress is zero. The mesh size and the time step was 0.1 mm and 1.12 ns, respectively. The input signal was up-chirp signal, whose frequencies are 0.5-1.5 (MHz) with duration of 10 μs. The center of transducer arrays is located at (X, 50) and (X, -50). Scanning pitch of X was 0.5 mm. A defect with diameter of 2 mm are located at the center of the cross section of measurement plane. Three kind of transmission patterns, transmission aperture a is 6 mm, a is 50 mm with plane wave and a is 50 mm with focused beam are performed. The left side of Fig. 2 shows the power of particle velocity between 0 and 25 μs. Focused beam are formed by summing up received signals from each elements of transmitter arrays setting time-delays. To simulate the noisy environment, white Gaussian noise were added with signal-to-noise ratio (SNR) of -10 dB to received signals of one elements when one elements transmit ultrasonic signal.

Figure 3 shows peak amplitudes of received signals at measurement and reference plane. From these figures, the effects of defect are confirmed even in noisy environment. The effect of noises are reduced by summation of transmitted and received signals. The effect of the defect becomes large when focused beam was used.

Figure 4 shows $\Delta\tau$ obtained by three kind of transmission patterns. The effect of noises are smaller than those of amplitudes shown in Fig. 3. Although peak value of $\Delta\tau$ are almost same, $\Delta\tau$ deviates only near the defect when beam focusing are used.

4. Conclusion

In this study, the validity of defect detection inside billet by ultrasonic transmission method using phased array technique. The effect of the defect on amplitude becomes large and $\Delta\tau$ deviates only near the defect even in noisy environment when beam focusing are used. As the future work, the experimental verification is planned.

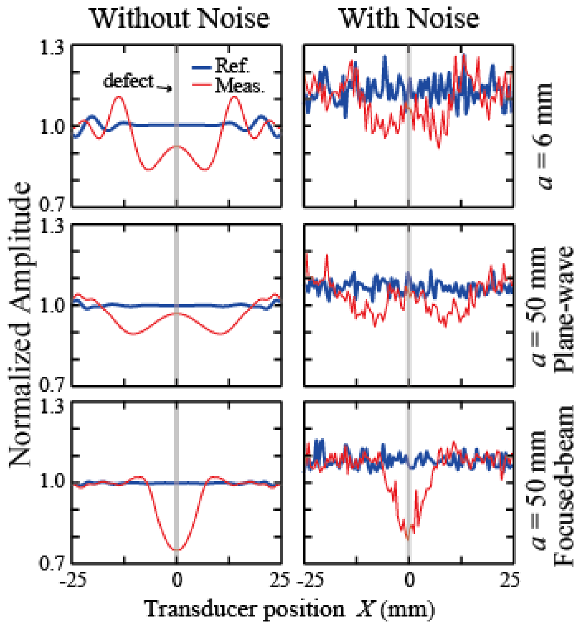

Fig. 3 Peak amplitudes of each transmitter arrays and transmitting wave shapes..

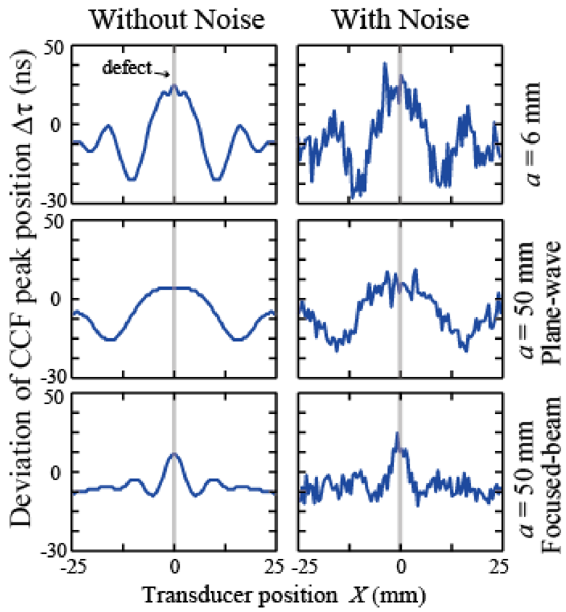

Fig. 4 Deviation of cross correlation function peak position $\Delta\tau$ of each transmitter arrays and transmitting wave shapes.

Acknowledgment

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References

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