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Size Estimation of Multiple Defects in Billet from Time-of-flight Profile by Transmission Method

透過超音波伝搬時間プロファイルに基づく角鋼片内部複数欠陥の径推定

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1. Introduction

We have proposed defect detection and size estimation method in billet from time-of-flight (TOF) profile by ultrasonic transmission method with linear scanning.[1)] This method can detect defects near the surface of a billet and obtaine larger intensity compared with conventional pulse echo method.[2)] By employing linear scanning, the measurement time is reduced compared with ultrasonic CT method using TOF. The validity of the defect detection and size estimation have been shown when there is a defect and are two defects with close proximity at same depth at measurement cross section.[1,3)] However, the validity of the method at different situation such as when there are multiple defects with different depth have not been shown.

In this study, the validity of defect detection and size estimation to defects with different depth from TOF profile by transmission method are evaluatted using wave propagation simulation.

2. Principle of defect size estimation

Figure 1 shows a scheme of defect detection and size estimation from TOF profile by transmission method. An ultrasonic signal is projected to a billet and received at opposite side. If there is a defect on the ultrasonic propagation path, TOF deviates by $\Delta\tau$. This deviation $\Delta\tau$ is obtained by calculating cross-correlation function between $m(t)$ and $r(t)$ as shown in Fig. 1. $m(t)$ and $r(t)$ are measured at measurement and reference plane with no defects, respectively. TOF profile, which is the relationship between transducer position X and $\Delta\tau$ is acquired by measuring a cross section of a billet using linear scanning. Defect size D is estimated from $\Delta\tau$ at the peak position in TOF profile, using relationship between D and $\Delta\tau$.

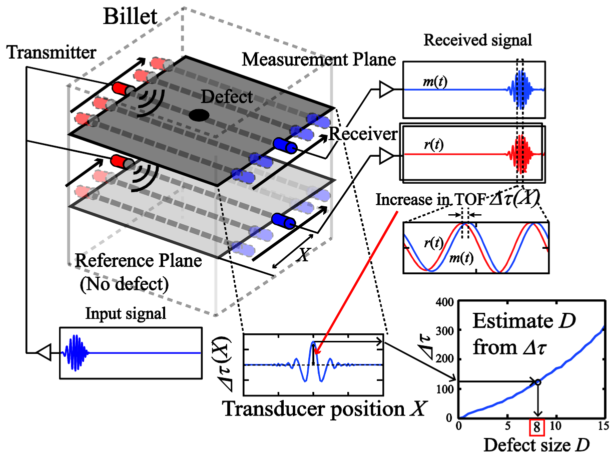

Fig. 1 Outline of defect size estimation from time-of-flight profile by transmission method.

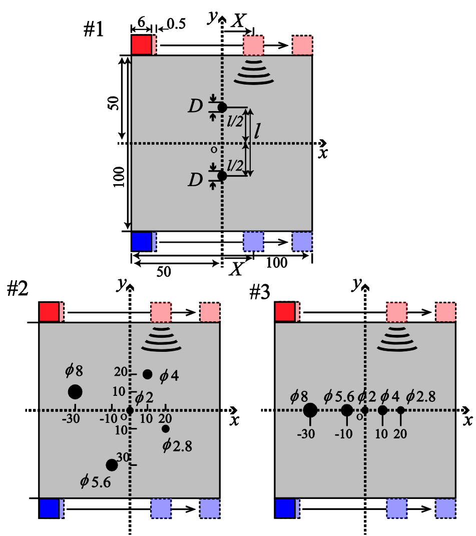

Fig. 2 Simulation conditions.

3. Numerical simulation

To simulate the wave propagation for defect detection and size estimation by the proposed method, two-dimensional finite-difference

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time-domain (FDTD) method for elastic wave in solid was employed.[4] In this simulation, isotropic elastic material was assumed. **Figure 2** shows the conditions of the 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 and 1.0-3.0 (MHz) with duration of 10 and 5 µs, respectively, windowed by Hann window. Transducers are located at (X, 50) and (X, -50). Scanning pitch of X was 0.5 mm. Three kind of cross section, #1, #2 and #3 are measured as shown in Fig. 2.

Figure 3 shows TOF profiles at #1. l means distance between two defects. l = 0 means that there is a single defect. From these TOF profiles, the number of defect is estimated as one when defects are at same x position with different depth y position. However, the size of the defect is not be underestimated compared with the actual size because $\Delta\tau$ is larger than that with a single defect. $\Delta\tau$ at X = 0 becomes large as l increases because the distance of ultrasonic propagation becomes large as l increases.

Figure 4(a) shows TOF profiles at #2 and #3, and Fig. 4(b) shows those at #2 when there is each defect singly. From Fig. 4(a), the effect of depth position of defects on TOF profile is small. The three defects with ϕ2, 2.8, and 4 cannot be detected because peak positions of TOF profile caused by defects are different from those at defect position as shown in Fig. 4(b) when f = 0.5-1.5 MHz. It was shown that the peaks of TOF profile appears at different position from the defect position when distance of defects are about 10 mm.[3] Although defect size estimation becomes difficult when defects are in close proximity, it can be known that there are multiple defect with distance of those two defect is about 10 mm from TOF profile which has peaks within 10 mm. At f = 1.0-3.0 MHz, the defects sizes can be estimated in these situation #2 and #3 although same difficulty occurs if distance between defects in x direction is shorter.

4. Conclusions

In this study, the validity of defect detection and size estimation to defects with different depth from TOF profile by transmission method are evaluated. Although defects can be estimated as single defect when defects are at the same position in x direction, the size of the defect is not be underestimated. In addition, whether there are multiple defects in close proximity or not can be known from the shape of TOF profile although sizes estimation of the defects are difficult. As the future work, experimental verification of the validity of propose method is planned.

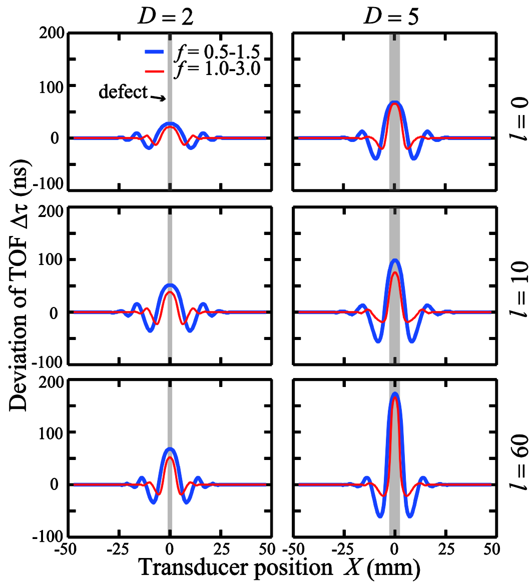

Fig. 3 TOF profiles at #1 when distance between defects l was changed.

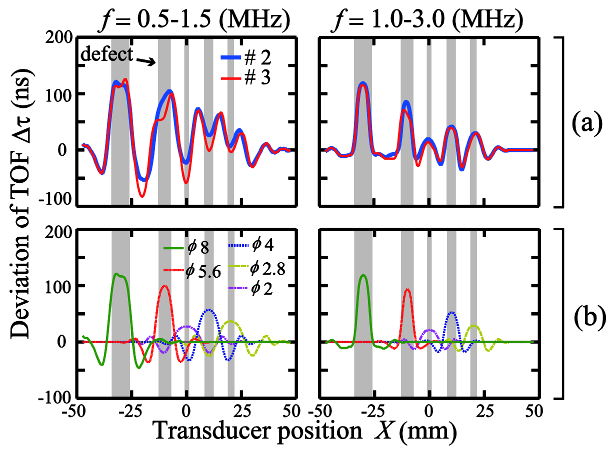

Fig. 4 TOF profiles at #2 and #3: (a) when there are 5 defects, and (b) when there is an each defect singly.

References

1. R. Miyamoto *et al*: Jpn. J. Appl. Phys. **54** (2015) 07HC11.
2. Y. Norose *et al*: Jpn. J. Appl. Phys. **53** (2014) 07KC19.
3. R. Miyamoto *et al*: Proc. Spring Meet. Acoust. Soc. Jpn. (2017) 1029.
4. M. Sato: Jpn. J. Appl. Phys. **45** (2006) 4453.