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Relationship between Probing Signal and Visualization Image for the Defect Detection of Billet Using Ultrasonic CT Method

超音波 CT 法を用いる角鋼片の欠陥検出における探査信号と可視化画像の関係性

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1. Introduction

Steel products are necessary for construction of buildings or manufacturing industrial products. These products are made by rolling and processing primary products called billets. In the manufacture of billets, they include defects infrequently, such as residual gas or metallic inclusion. From the aspects of production efficiency of steel products and quality of end-products, it is desirable to detect the defects at a stage of billets. As non-destructive inspections technique of billets, ultrasonic pulse-echo technique is commonly used. However, this is not adequate to detect defects that locate near the surface or that are tiny. Therefore, ultrasonic computerized tomography (CT) method using time of flight (TOF) of longitudinal wave have proposed [1-3]. This technique is expected to solve the problem of ultrasonic pulse-echo technique and in this research, we utilize ultrasonic CT method using TOF.

Figure 1 shows billet and measurement plane. A billet including a defect is shown in Fig. 1(a). In a measurement plane that is cross-section of the billet, the defect detection is performed. Measurement of the pseudo osund velocity distribution on a measurement plane is performed by scanning the ultrasonic transducers around the surface. This inspection is performed over the whole billet by shifting the measurement plane toward to the longitudinal direction of the billet. An example of the pseudo sound velocity distribution is shown in Fig. 1(b). According to Fig. 1(b), defect appears near-field region of defect as decrease of pseudo sound velocity. In our previous research, we found that the extent of defect of visualization image is related to probing signal [4]. However, it is not considered well about the effect of probing signal characteristics (e.g. frequency, signal length) on the extent of defect as visualization image. Therefore, our purpose is to clarify the relationship between frequency of probing signal and the extent of defect image by simulation.

2. The Principle of Defect Detection

Figure 2 shows the flow of defect detection by our method. Propagation path of ultrasound and resulting TOF are shown in Fig. 2(a). Propagation paths between transducers are shown in Fig. 2(b). Distribution of pseudo sound velocity (visualization image) is shown in Fig. 2(c). Binarized image of the distribution is shown in Fig. 2(d).

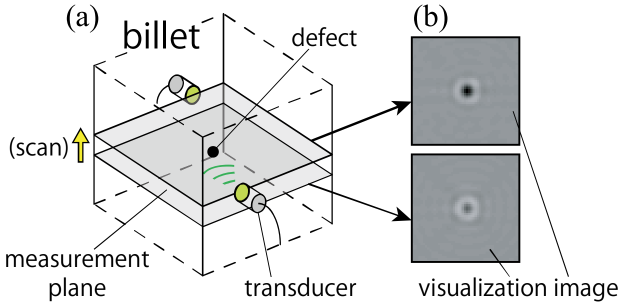

Fig. 1 Billet and measurement plane. (a) A billet including a defect and (b) visualization images in measurement planes.

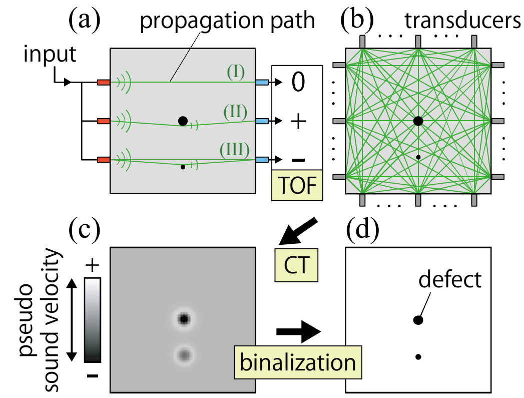

Fig. 2 Flow of defect detection. (a) Propagation path of ultrasound and resulting TOF, (b) propagation paths, (c) distribution of pseudo sound velocity, and (d) Binarized image.

First, deviation of TOF between two transducers located around measurement plane is measured. As shown in Fig. 2(a), there are three cases; propagation path (I) does not pass through defect, (II) passes through defect, and (III) passes through near defect. In the case of (I), deviation of TOF is 0 because TOF is free of the influence of defect. In the case of (II), deviation of TOF becomes positive because propagation path stretched the defect. In the case of (III), deviation of TOF becomes negative apparently because of the influence of interference between scattered wave by defect and direct wave. Deviations of TOF are obtained in each propagation paths such as Fig. 2(b).

CT method is applied to deviations of TOF, and distribution of pseudo sound velocity is obtained as shown in Fig. 2(c). Decrease of sound velocity is shown at the place of defect, and increase of the velocity is shown around that place apparently. By binarizing pseudo sound velocity, defect detection becomes possible as shown in Fig. 2(d).

3. Simulation

3.1 Simulation conditions

We look at the relationship between frequency of probing signal and the extent of defect in visualization image by simulation. Billet is assumed to be steel whose sound velocity is 5,950 m/s. Measurement plane is 100 × 100 (mm^2). In the center position of the plane, circular defect of 2 mm is located. We use finite-difference time-domain (FDTD) method for this simulation.

The analytic area is discretized at 0.1 mm intervals, and simulation time is discretized at 0.12 μs. Transducers whose aperture sizes are 2 mm are located around measurement plane. On a side of the plane, 50 transducers are located at regular intervals. Probing signal is up-chirp signal whose length is 5 μs. This signal is multiplied by a Hanning window. Center frequency is defined as f_c and sweep width of frequency is defined as Δf.

3.2 Results and discussions

Distributions of pseudo sound velocity and setup defect are shown in **Fig. 3**. The diameters of visualized defect differ according to conditions. In **Fig. 4**, we show some parameters whose value are changed with frequencies. Changes of the diameters d are shown in Figs. 4(a) and 4(b). The diameters of defect are nearly-constant against changes of sweep width as shown in Fig. 4(a). However, the diameter of defect change depending on center frequencies like Fig. 4(b). Therefore, it is found that the extent of defect in visualization image is determined by the center frequency of the probing signal.

Wavelengths according to center frequencies are shown in Fig. 4(c). And, the diameters of defect divided by wavelengths λ are shown in Fig. 4(d). In this figure, the value of d is used from d in Fig. 4(b), when Δf is 1 MHz. Focusing on Fig. 4(d), there is a non-linear relationship between d/λ and f_c. In other words, the extent of defect in visualization cannot bze determined by wavelength directly. Therefore, we should estimate the extent of defect by making approximately curve of f_c-d.

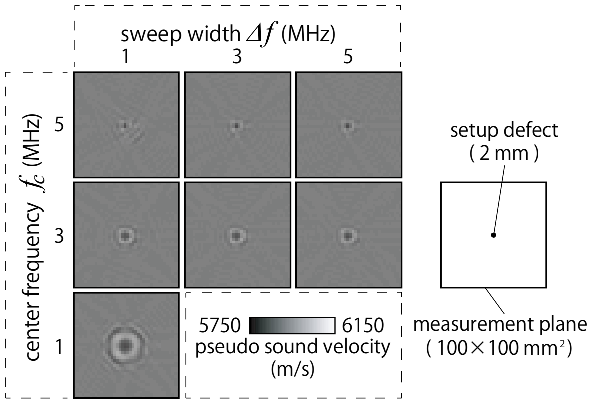

Fig. 3 Distributions of pseudo sound velocity and setup defect.

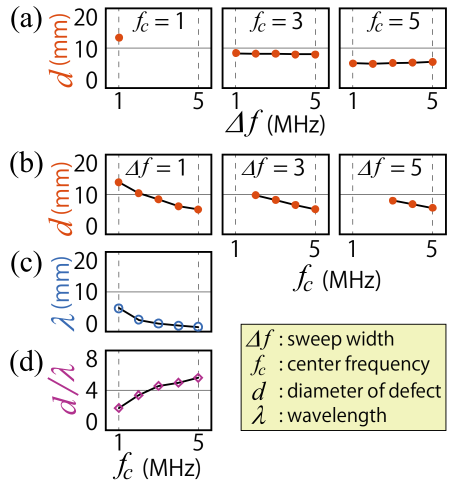

Fig. 4 The diameters of defect according to (a) sweep width of frequency, (b) center frequencies, (c) wavelengths according to center frequencies, and (d) the diameters of defect divided by wavelengths according to center frequencies.

4. Conclusions

We simulated relationship between frequency of probing signal and the extent of defect image in visualization image. As a result, we found that the extent is determined by center frequency. Then, we compared that extent and wavelength. However, there was non-linear relationship between them. Therefore, we found that we should estimate the extent of defect by using approximately curve.

References

1. K. Kakuma, Y. Norose, K. Mizutani, and N. Wakatsuki: Jpn. J. Appl. Phys. **52** (2013) 07HC10.
2. Y. Norose, K. Mizutani, and N. Wakatsuki: Jpn. J. Appl. Phys. **51** (2012) 07GB17_1-6.
3. H. Mitsui, K. Mizutani, N. Wakatsuki, and Y. Norose: Jpn. J. Appl. Phys. **50** (2011) 116601_1-9.
4. Y. Norose, K. Koichi, and N. Wakatsuki: Journal of Japan Society of Civil Engineers, Ser. A2 (Applied Mechanics) **68** (2012) pp. I_810I_88.