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# Visualization for Near-defect Region in Billet Using Ultrasonic CT Method

超音波 CT 法を用いる角鋼片内部の欠陥近傍領域の可視化

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## 1. Introduction

Iron products such as automobiles, buildings, or airplanes are used a lot in our modern daily lives. Steel products used in iron products are made by rolling or processing semifinished products called billets. They are made by continuous casting of molten steel. At the casting process, defects by air bubbles or inclusions may arise inside billets. Since they deteriorate quality of final iron products and production efficiency of steel products, it is desirable to detect them nondestructively in the stage of semifinished products. Ultrasonic flaw detection method is an effective way of nondestructive inspection of defects inside billets. In this research, ultrasonic computerized tomography (CT) method using time of flight (TOF) of longitudinal wave is utilized[1-3]. This method is one of ultrasonic flaw detection method. It is suitable for detection of defects because combined use of TOF and CT can visualize sizes and locations of defects.

Billets including a spherical defect is shown in **Fig. 1**. In previous research, detection simulation of circular defects on an analyzed plane or detection experiment using deep hole defects have been conducted. However, spherical defects like air bubbles are included in actual semifinished products in many cases. So in this research, simulation of visualization was performed in some analyzed planes near defect supposing three-dimensional billets including a spherical defect. Moreover, differences in simulation results by distance of the defects and analyzed planes were considered.

## 2. Principle of Defect Visualization

An analyzed plane is shown in **Fig. 2**. Ultrasonic propagation paths between transmitter and receiver are shown in Fig. 2 (a). If defect is off the path, TOF of direct wave may be observed. If a defect is on the path, TOF of diffracted wave may be observed. Compared with the case that no defect is on the path, the case that a defect is on the path causes increase in TOF. If the defect is near the path, TOF decreases due to influence of the interference between direct and diffracted wave.

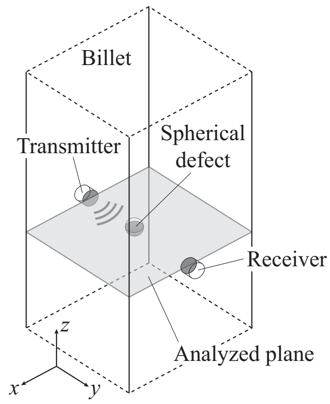


Fig. 1 Billet including spherical defect.

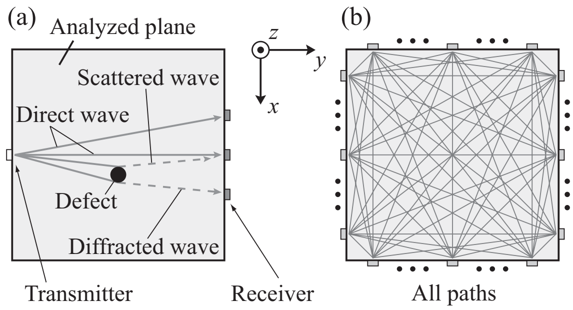


Fig. 2 Analyzed plane: (a) direct, diffracted and scattered waves and (b) propagation paths.

Propagation paths between transducers placed on outer periphery of billet are shown in Fig. 2 (b). TOF is measured in analyzed plane include defects and in reference plane without defects, and deviation of TOF is calculated in all paths. By applying the CT method, pseudo velocity distribution is obtained. Since decrease of velocity is seen in part where defect exists and increase of velocity is seen around that, detection of defect is attained.

## 3. Simulations

### 3.1 Simulation conditions

A simulation of three-dimensional wave propagation is performed using finite-difference time-domain (FDTD) method. The object is iron (sound velocity is 5,950 m/s) of 100×100×150 ($mm^3$) which includes spherical defect of 5 mm diameter in the center position. The analytic area was dispersed by the width of 0.25 mm and the mesh space of 401×401×401 was obtained. Gaussian pulse which has about 2.969 MHz in bandwidth was used for the transmitted signal. In each path, received signals for 25 μs were acquired. Transducers are assumed to be point sound sources. By calculating a cross-correlation function between received signals in analyzed plane and reference plane, deviation of TOF is obtained. Pseudo velocity distribution is obtained by applying the CT method.

Conditions of simulation are shown in **Fig. 3**. Analyzed plane through center of spherical defect is shown in Fig. 3 (a). 50 transmitters are arranged on the left-side boundary of Fig. 3 (a) and 50×3 receivers are arranged on other side boundaries. These transducers are placed so that they become regular intervals at intervals of 2 mm and become symmetrical to the median line of each boundary. *X* and *Y* represent positions of transmitter and receiver. Longitudinal section A-A' in Fig. 3 (a) is shown in Fig. 3 (b). Fig. 3 (a) is equality to analyzed plane (i). Analyzed plane (ii) and (iii) are cross sections which locate over 10 and 20 (mm) on the plane (i), respectively. Defect detection simulation is performed in each plane.

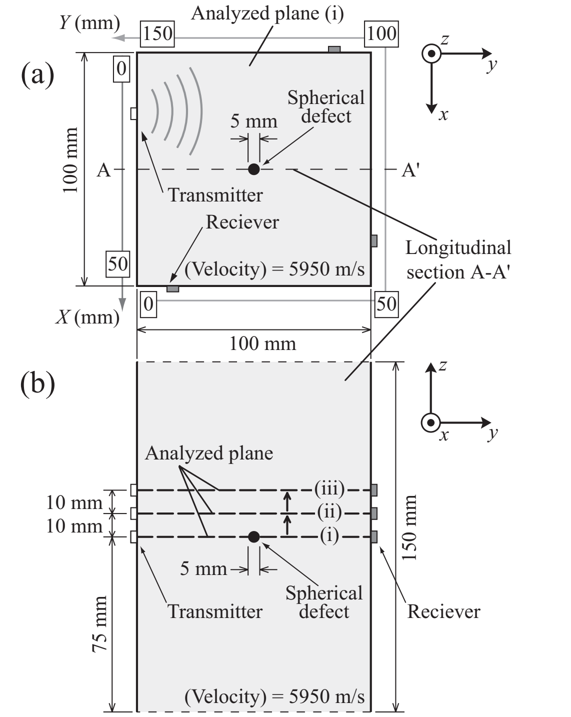


Fig. 3 Schematic view of simulation: (a) Analyzed plane and (b) longitudinal section.

### 3.2 Results and discussion

Simulation results in (i), (ii) and (iii) in Fig. 3 (b) are shown in **Fig. 4**. Deviation of TOF is shown in Fig. 4 (a). White and black part mean increase and decrease of TOF, respectively. In (i), increase of TOF is shown when defect is on the path, and decrease of TOF is shown when defect is near the path. In (ii), decrease of TOF is shown when defect is near the path. In (iii), deviation of TOF can be neglected. It was found that if analyzed plane is circumference of defect, deviation of TOF will be observed even when no defect is on it.

Distributions of deviation of pseudo sound velocity obtained by applying the CT method are shown in Fig. 4 (b). Black part means decrease of velocity and white part means increase of velocity. In (i), decrease of velocity is shown in the center, and increase of TOF is shown near the center. In (ii), increase of TOF is shown in the center. In (iii), deviation of velocity is almost lost. It was found that if analyzed plane is offset from defects, they may be detectable.

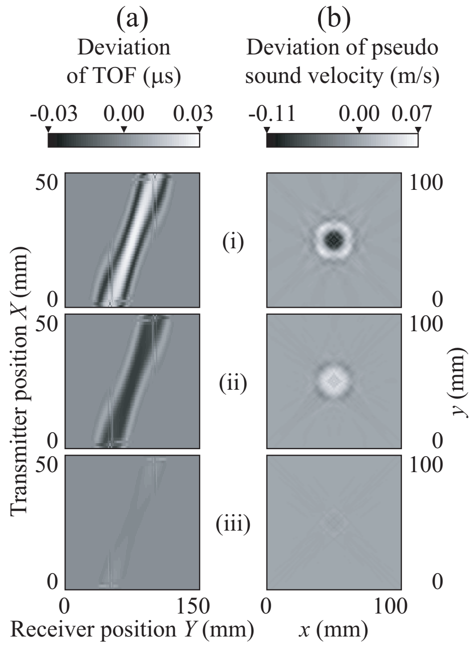


Fig. 4 Simulation results of (i), (ii) and (iii) in Fig. 3: (a) deviation of TOF and (b) distributions of deviation of pseudo sound velocity.

### 4. Conclusions

By supposing three-dimensional billets including a spherical defect, visualization simulation was performed in some analyzed planes near defect. Deviation of TOF and deviation of pseudo sound velocity were compared. As a result, it was found that defects may be deflectable when analyzed plane is offset from them.

### References


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