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Phased array imaging with a stacked plate buffer

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1. Introduction

Phased array ultrasonic testing has been used in recent years for various non-destructive testing (NDT) applications in areas including medical, nuclear power, and materials evaluation. A phased array transducer has many advantages compared to normal transducer including providing the capability of signal focusing and steering at desired angles and locations. [1,2)]

However, challenges appear for testing high temperature objects. Phased array transducers will be destroyed when directly contacting with the object with high temperature. Although a buffer rod may be a candidate that allows to connect the transducer and the object, it will limit the detecting range of the phased array transducer. Thus, a buffer which can keep the original performance is needed.

The method of solving this problem was investigated by a previous study. [3)] In that research, a method of ultrasonic focusing using a stacked plate region with the same thickness was demonstrated, and it was shown that the longitudinal wave could be focused by delaying the incident wave on each thin plate. The focusing performance when using the stacked plate region was same as focusing without a buffer. Moreover, the stacked thin-plate region enabled us to focus on a distance that could not be focused using conventional buffer rods. Therefore, a stacked thin-plate region is expected to be applied in fields where phased-array transducers cannot be attached directly, such as non-destructive inspection of high-temperature objects. [3)]

Inspired by the previous research, in this study, we tested the effectiveness of defect imaging using phased array transducer with a stacked plate buffer. This buffer can decrease the limitation of the detecting range to the phased array transducer from the buffer which consisted of a single rod buffer. Numerical calculations are applied to confirm the performance of the stacked plate buffer.

2. Methodology

In this research, we utilize the stacked plate buffer to connect a linear phased array transducer and the specimen to transmit the signals. The scheme of the calculation model is shown in **Fig. 1**. Because the specimen is considered to be large enough, the absorption regions are attached on the left, right and bottom edges to suppress the reflected waves. The imaging area is surrounded by red dash lines. This specimen has two defect holes, and the radius of each hole is 2 mm. The center of the bottom of the stacked plate region is defined as the origin of the *xy* coordinates, and the positions of the defects are expressed as (*x, y*). The positions of defect 1 and defect 2 are (-10 mm,15 mm) and (5 mm, 25 mm), respectively. The stacked plate buffer consists of 16 plates. All the plates have 0.9 mm thickness in the *x* direction and 60 mm length in the *y* direction. The width of the gaps between each plate is set to be 0.6 mm. The upper ends of the plates are bonded to the transducer elements by element, and a pulse with 1.0 MHz longitudinal wave is propagated from the upper end of each plate to the lower end. Free traction boundaries are set on the upper and lower boundaries of each plate in the stacked plate buffer.

In order to verify the effectiveness of the proposed stacked plate buffer in the phased array imaging, numerical calculations using COMSOL Multiphysics® were performed. Two different defect imaging techniques are used, plane wave imaging (PWI) and full matrix capture (FMC), which are often used in non-destructive testing when using phased array transducer. These two different methods were tested when using a stacked plate buffer and find the differences between these two methods in the results of defect imaging of specimen.

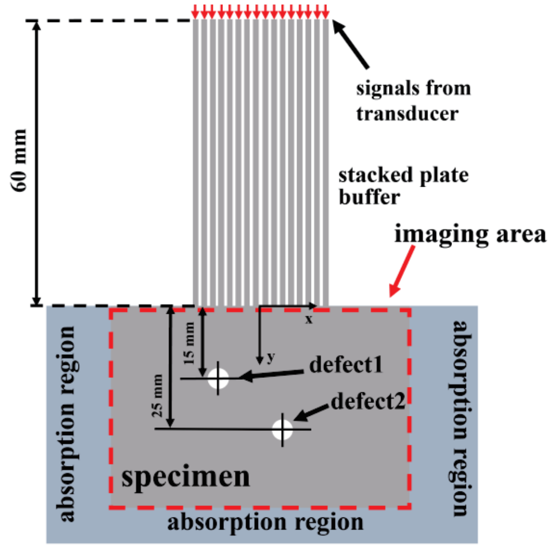

Fig. 1 Structure of the model in numerical calculation.

3. Results

The results of defect imaging are shown in **Fig.**

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2 and **Fig. 3**. In these results, echoes from the defects in the specimen can be successfully received at the transducer positions and the defect images were successfully achieved. Shown in **Figs. 2** and **3,** the color represents the intensity of phase matched waveforms processed by all signals at the elements. The high intensity positions are (-10 mm, 15 mm) and (5 mm, 25 mm), respectively, whose centers agree well with the positions of defects on the specimen.

When the wave transmitting through the stacked plate buffer and colliding with the interface between the specimen and plates, only a part of the energy of the wave was transmitted into the specimen, while the remaining energy of the wave will be reflected back to the plate buffer. The reflected wave will propagate back and forth in the buffer for several rounds between the left end of the buffer which is bounded with transducer and right end of the buffer which is contact with the specimen. Thus, several echoes of the reflected waves between left end and right end of the buffer for several times will be received. Because of the limitation for the calculation time, in the result shown in **Figs. 2** and **3**,

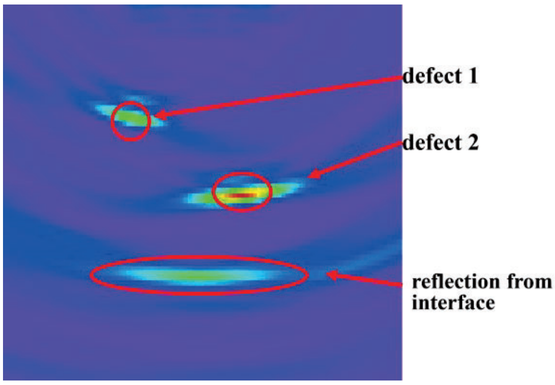

Fig. 2 Result of the defect imaging by PWI.

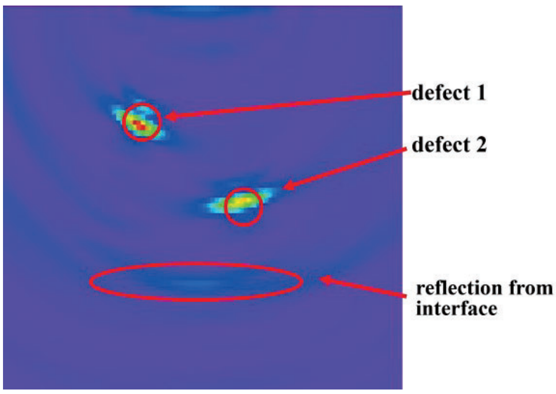

Fig. 3 Result of the defect imaging by FMC.

the signals were calculated up to the second time reflection from the interface and were included in the process of the imaging. The reflection from the interface can be observed below the positions of two defect echoes, as well as the spurious images due to the interface echoes.

The differences between the FMC and PWI can be observed from the results. By using the FMC, the strength of the echo from the interface between the buffer and the specimen can be smaller than that when using PWI method. This is because only one element generates the incident wave and the other 15 elements do not have significant echoes of the reflected waves within the buffer plates.

4. Conclusions

This research proposed the phased array imaging with a stacked plate buffer which can keep the original performance of the phased array transducer to some extent. The model of the stacked plate buffer was designed to be paired with the phased array transducer and successfully transmit the ultrasonic wave to the specimen. Two different imaging techniques, plane wave imaging (PWI) and full matrix capture (FMC), are used to test the effectiveness of the stacked plate buffer.

In the future work, more factors needed to be considered in the numerical calculation. In the calculation shown in this research so far, the contact of the interface between buffer, transducer and specimen is perfectly continuous in displacement and stress. However, these contacts more likely to be point contact in practical applications. In that case, the reflection from the surfaces will be stronger than that observed in the result of this research. Moreover, the specimen may not always large enough. Therefore, the reflections from the boundaries of the specimen are needed to be considered. The influences from these reflections to the performance of defect imaging are needed to be investigated. After finishing the calculations which considered more factors, the experiments should be done to confirm the effectiveness of the stacked plate buffer in practical application.

References

1) F. Dupont-Marillia, M. Jahazi, S. Lafreniere, and P. Belanger, *NDT and E International* **103**,119–1 (2019)
2) H. Taheri, and A. A. Hassen, *Appl. Sci.* **9**, 1628 (2019).
3) T. Fukuchi, T. Hayashi, and N. Mori, Jpn. J. Appl. Phys. **62**, SJ1005 (2023).