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Characteristic Assessments of the Phased Array UT System Developed by KHNP

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1. Introduction

The ultrasonic testing (UT) is an important one of the nondestructive examination methods which are used for the in-service inspection in the nuclear power plant. It is mainly used for the inspection of welds in piping and nozzle for many components. Technologies for the ultrasonic testing have been advanced for the reduction of inspection time and the increase of inspection reliability. In the manual ultrasonic testing system, it is not easy to compare the variation of inspection signals over time, because the data cannot be stored during the inspection. Therefore it is important to store inspection signals by the automated ultrasonic testing system with encoders in scanner systems. Several times of inspection with different degrees of wedges for the same location are needed in the pulse-echo manual UT system. This is regarded as the time-consuming method. Therefore, the phased array UT system with the scanner has been developed in order to overcome these barriers of conventional UT inspection methods. The Korea Hydro & Nuclear Power Co., Ltd. (KHNP) is developing the phased array UT system and the specified scanner system for the inspection of nuclear power components. Details of these systems are described in this paper.

2. Scanner and Phased Array Probe

Phased array UT technology allows for the generation of an ultrasonic beam with the possibility of modifying the beam parameters such as angle, focal distance, and focal spot size through software. Furthermore, this beam can be multiplexed over a large array, thus creating a movement of the beam along the array. These capabilities open a series of new possibilities; for example, it is possible to quickly vary the angle of the beam to scan a specimen or weld without moving the probe itself, phased array also allows the replacement of multiple probes, and mechanical scanning devices. Inspecting a specimen or weld with variable angle beams also improves detection of defects[1].

2.1 Scanner System for Phased Array UT Technology

There are two types of ultrasonic testing such as manual UT and automated UT. In the automated UT technology with scanner, remote inspection can be performed, digital data can be stored, and the results can be expressed by the B-Scan, C-Scan, and S-Scan. Conventional scanners for automated UT inspection are based on two axes such as index-axis and scan-axis as shown in Fig. 1. Motor drive device and timing-belts are included in this type of scanner so that the ultrasonic probe can scan to axial and circumferential directions.

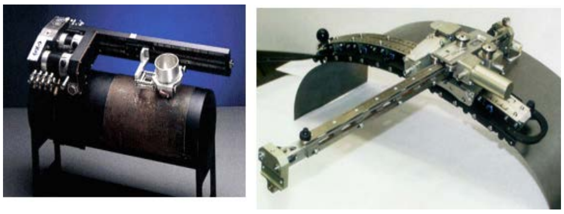

Fig. 1. Two-axes conventional automated scanner

It is not easy to inspect the welds with complex geometry surface such as inclined planes and dissimilar nozzles. Appropriate angles are needed between the scanner body and the arm for the inspection of complicated shape surface. For this purpose, the KHNP designed the advanced scanner with three directional degrees of freedom as shown in Fig. 2 and Fig. 3.

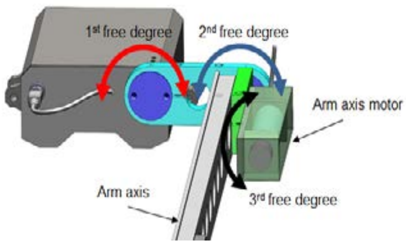

Fig. 2. Scanner with 3-directional degree of freedom

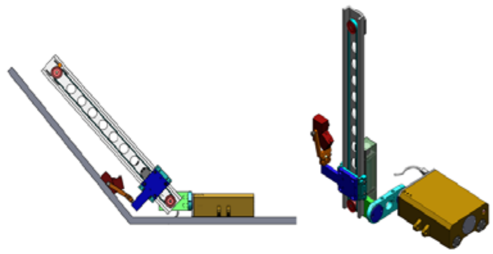

Fig. 3. Design concept of an automated scanner

2.2 Phased Array Probe

The phased array UT system developed by the KHNP is composed of PA probe, pulser-receiver, AD converter, beam-former, FPGA controller, CPU board, scanner, motor drive unit (MDU), data acquisition PC, and acquisition-analysis software [1]. The analog boards of pulser and receiver transmit excitation signals and amplify received signals. The digital boards perform focusing beams and play a role of post signal processing.

The MDU moves a scanner with a probe for the scanning inspection spot. The KHNP developed a phased array probe for the inspection of piping welds in nuclear power plants. Fig. 3 shows the manufacturing process of the KHNP phased array probe and electrical characteristics of the phased array probe listed in the Table 1.

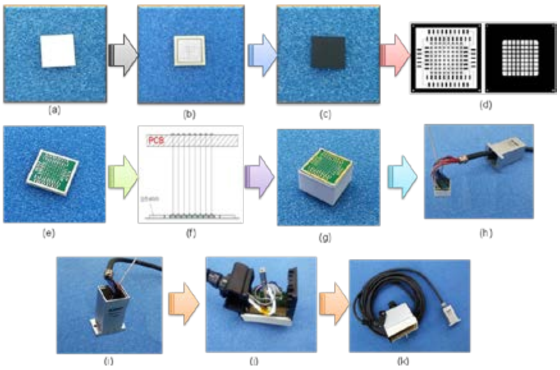

Fig. 4. Manufacturing Process of the PA probe

Table 1. Electrical characteristics of the PA probe

Electrical Characteristics		value
Relative Dielectric Constants	$\varepsilon^T_{33} / \varepsilon_0$	5500
Dielectric Loss Factor	Tan δ (%)	2.3
Electro Mechanical Coupling Coefficient	K31 (%)	35
	K33 (%)	70
Piezoelectric Strain Constants	d31 ($x10^{-12}$m/V)	310
	d33 ($x10^{-12}$m/V)	660
Voltage Output Constants	g31 ($x10^{-3}$V·m/N)	6.0
	g33 ($x10^{-3}$V·m/N)	13.0

The software for the signal acquisition and analysis was developed for various scan frames such as A-scan, B-scan, C-scan, and S-scan as sown in Fig. 5. Also signal filtering algorithm was applied in this software. Fig. 5 shows the data acquisition signals after filtering process.

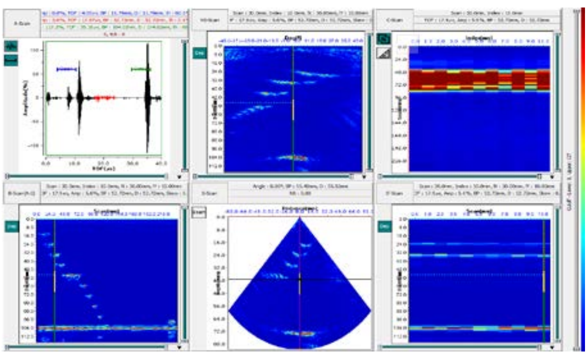

Fig. 5. Data acquisition and analysis software

3. Results

The signal linearity was identified using 20mm stainless steel specimen and 5MHz, 64 elements, 1mm pitch phased array probe as shown in Fig. 6. Acquired signals are shown in Fig. 7 and signal linearity can be established as the artificial drilled holes. The calibration block with Φ1mm and Φ2mm of side drilled holes was used for the performance verification testing of the KHNP phased array system and the results are shown in Fig. 8.

Fig. 6. PA probe and stainless steel specimen

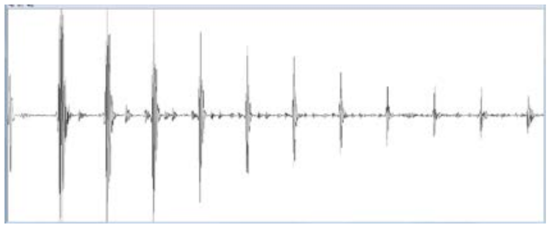

Fig. 7. A-Scan signals acquired using the KHNP probe

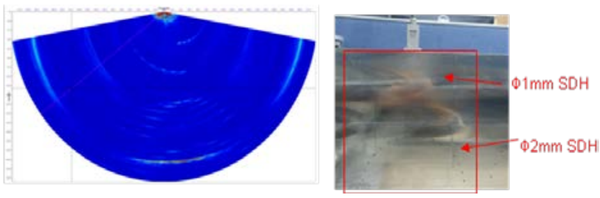

Fig. 8. S-scan signals of calibration block with SDHs

4. Conclusions

For the purpose of inspecting nuclear power components, the KHNP developed a phased array UT system including pulser-receiver, AD converter, beam-former, phased array probe, and scanner with 3-directional degree of freedom. Characteristics of the KHNP PA system and the results of acquired signals are described in detail in this paper.

REFERENCES

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