Development of Phased Array Ultrasonic Testing Procedure for NPP Class 1 Piping Welds

Byung-Sik Yoon*, Seung-Han Yang, Yong-Sik Kim, Hee-Jong Lee
Korea Electric Power Research Institute, 305-380 Munji-Dong,Yuseung-Gu, Daejoon, 305-380, Korea
**Corresponding author: bsyoon@kepri.re.kr*

1. Introduction

Most of the piping welds at nuclear power plants are inspected periodically using ultrasonic techniques to detect service-induced flaws such as IGSCC cracking. However majority of costs are associated with these inspections. The inspection equipment, procedures, and personnel must be qualified by demonstration according to ASME Code Section XI appendix XII requirements. Also the inspections in the nuclear power plants are time-consuming and result in radiation exposure to inspector. Furthermore, errors in data acquisition or interpretations can lead to additional costs if rescans are necessary or if components are repaired unnecessarily. Newer phased array ultrasonic techniques could reduce these costs; however, until recently, no inspection services vendors were prepared this technique to apply in field inspection. In this study, we developed procedure and qualified a procedure for inspection of piping welds at nuclear power plants using phased array ultrasonic technology. The procedure is qualified for detection and length measurement. The new procedure provides improved data quality in less time than is required for inspections using conventional ultrasonic technology. The time savings can result in reduced radiation exposure to personnel, and the high quality of the data can lead to savings in rescanning and repairs.

2. Procedure Development

2.1 KPD Qualification Range

The KPD(Korean Performance Demonstration) system developed by requirement of ASME code. This system covers all piping weld geometry of Korean nuclear power plant. The diameter of piping is to 50.8 mm(2 inch) from 1,270mm(50 inch) and the thickness range is 5.5mm(0.21inch) from 97.79mm(3.85inch). The procedure developed to cover below table 1 range due to the scanner attachment and the size of phased array transducer. Table 1 shows procedure cover range.

Table 1 Piping geometry range for procedure

Material	Diameter (mm)	Thickness (mm)
Ferritic	21.60~1,270 (4"~50")	8.56~97.79 (0.337"~3.85")
Austenitic	21.6~609.6 (4"~24")	6.02~38.1 (0.237"~1.50")

2.2 Phased Array Probe Design

The phased array probe is a close arrangement of small transducers, called elements, in a single probe body. The phased array ultrasonic equipments control excitation(amplitude and delay) of individual element in as multi-element probe. And excitation of piezo-element can generate an ultrasonic focused beam with the possibility of modifying the beam parameter such as angle, focal distance, and focal spot size through software. The phased array probe design must be advanced to produce proper beam characteristic.

For the piping application, we developed an inspection procedure using two-dimensional pitch-catch phased array probes to scan for detection and length measurement of cracks oriented in either the circumferential or axial direction. Fig. 1 shows examination coverage plot by ASME code requirement.

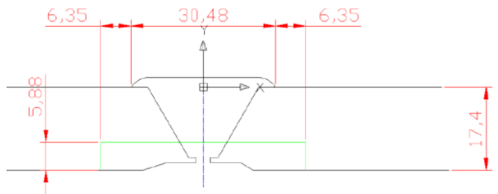

Fig. 1 Examination coverage plot

Phase array probe selected after evaluation for every pipe configuration. Table 2 shows the selected phased array probe characteristics.

Table 2 Selected phase array probe characteristics

Probe size	S	M	L
Pipe OD	4″~6″	12″~24″	>24″
Frequency	3.5	1.5	1.5
Primary Element	5	5	8
Secondary Element	3	3	4
Primary Pitch	1.5	3.5	3.5
Secondary Pitch	1.5	3.0	4.0

2.3 Phased Array Probe Wedge Design

The phased array probe has to assemble with wedge to produce proper wave mode. For the 304.8mm(12 ″) diameter piping, the wedges for the axial shear technique have a wedge angle of 33.2° and a roof angle of 12.1°, the footprint of the wedge assembly has been minimized to 36 x 36.3 mm. The wedges shall be contoured to the curvature of the component.
With these wedge parameters, when applying no electronic steering, the geometrical intersecting point of both beams for a 48° shear wave falls at a depth of 13

mm, taking into account the cylindrical surface. For a 304.8mm(12 ˝) pipe, the following fig. 2 show the coverage that can be achieved with the front of the wedge as close as possible to the weld cap, i.e. 15.2 mm from the weld center line. The highest angle (70°T) just touches the end of the examination volume at the inner diameter.

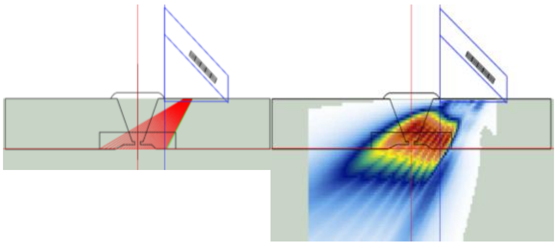

Fig. 2 Phased array ray tracing and beam modeling for coverage evaluation with designed probe and wedge

2.4 Phased Ultrasonic System

The phased array ultrasonic equipment has to involve qualification and field application. The Dynaray (ZETEC) phased array 128 channel system used in this study. The digitization frequency of phased array system is 100MHz and the signal resolution is16 bit. The motorized two axis scanner used to perform automatic inspection.

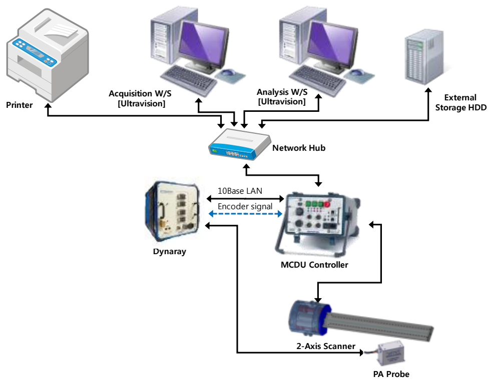

Fig. 3 Schematic diagram for procedure qualification.

2.5 Phased Ultrasonic software

The phased array ultrasonic data acquisition and analysis software developed for Korean nuclear power industry application. Fig. 4 shows main screen of developed SonicStation phased array software.

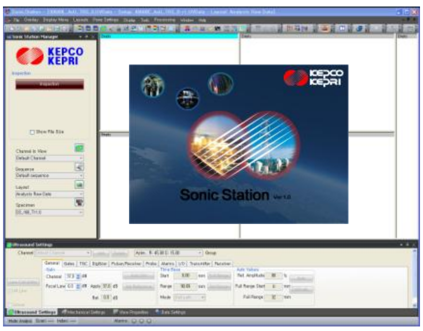

Fig. 4 SonicStation main window

3. Qualification Results

The procedure was qualified for flaw detection and length measurement to the requirements of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, Appendix VIII, Supplements 2 and 3, through the program administered by the Korean Performance Demonstration(KPD). The qualification includes ferritic piping, austenitic piping, and austenitic piping with thermal and mechanical crack. The qualified diameter range is 12-inch nominal pipe size (324-mm outside diameter) to 50-inch nominal pipe size (1.27-m outside diameter).

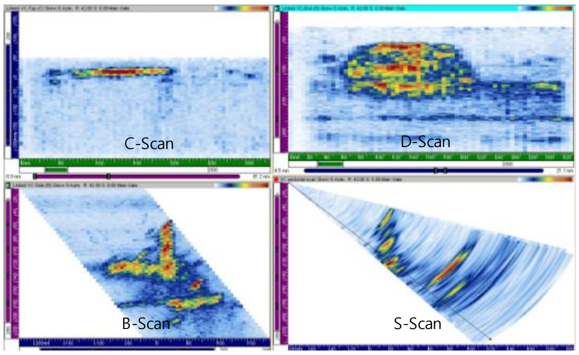

Fig. 5 Signal display from practice sample

This supports the use of arrays and cabling that have experienced some degree of normal wear. A 150mm extension cable was used in addition to the 10m integral cable on each probe array.

The technique produced very high-quality data. Almost no rescanning was necessary. Both scanning and data analysis were very quick in comparison to conventional technologies.

4. Conclusions

In this study, phased array technique developed for nuclear power plant piping inspection. Consequently, we propose the following results.

1. The phased array probe and wedge designed and evaluated for procedure development.
2. The phased array procedure developed for performance demonstration and field application.
3. The phased array procedure successfully qualified to detection & length sizing and depth sizing according to ASME Section XI Appendix VIII requirement.

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