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Phased Array Ultrasonic Examination for NPP Piping Welds

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1. Introduction

Piping welds at nuclear power plants are inspected periodically using ultrasonic techniques to detect service-induced degradation such as cracking. Many costs are associated with these inspections. The inspections in power plants are time consuming and result in radiation exposure to personnel and errors in data acquisition or interpretations can lead to additional costs if rescans are necessary or if components are repaired unnecessarily. The inspection equipment, procedures and personnel must be qualified by ASME B & PV code, Sec. XI, Appendix VIII performance demonstrations [1]. There is no qualified procedure using phased array technique to detect flaw in KPD (Korean Performance Demonstration) piping program. This technique can reduce these costs and increase the detection, availability and reliability compared to automated conventional pulse echo UT technique in piping examination.

2. Experiments

In this section piping specimen, UT technique, experiment setup and results are described.

2.1 UT Specimen

Piping specimen for performance demonstration is used in the experiment. This piping specimen is 12 inches diameter, schedule 80 and nominal thickness 0.688 inches. The material is austenite stainless steel and sectioned in half like shown in figure 1. Specimen includes two flaws. One is shallow flaw and another is deep flaw with different length.

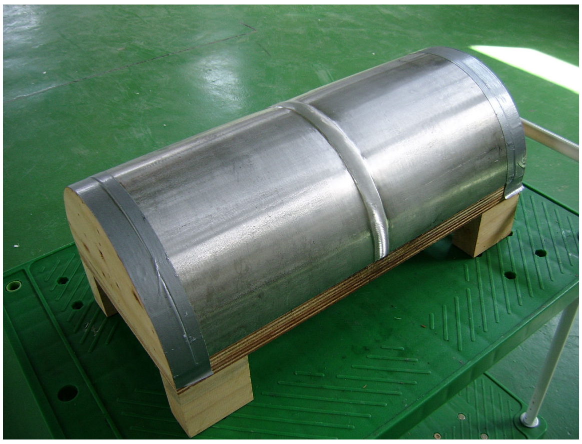

Figure 1. Piping specimen for performance demonstration.

2.2 UT Technique

Conventional UT technique uses pre-determined sound beam angle by procedure to detect cracks. Phased array UT technique can make certain range of sound beam angle. The advantage of phased array UT technique is that the interested area is examined at once.

2.3 Experiment setup & results

10 MHz and 32 element phased array UT transducer is used. 0° ~ 80° ultrasonic shear wave are made at 0.5° degree interval. Manual hand scanner with encoder is used and encoder resolution is 1 mm.

Figure 2, 3, 4 show side scan image obtained from specimen at 31°, 33° and 37° shear wave. The signals from flaws are indicated and signal amplitudes are shown by color. From these figures, length sizing can be estimated using 6dB, 12dB or fully drop method considering shear wave propagation degrees.

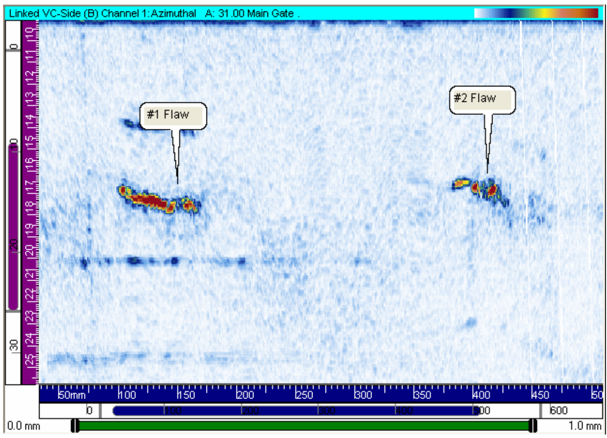

Figure 2. Side scan image at 31° ultrasonic shear wave

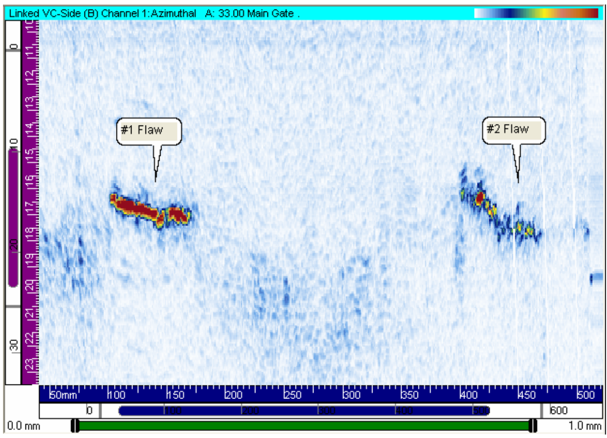

Figure 3. Side scan image at 33° ultrasonic shear wave

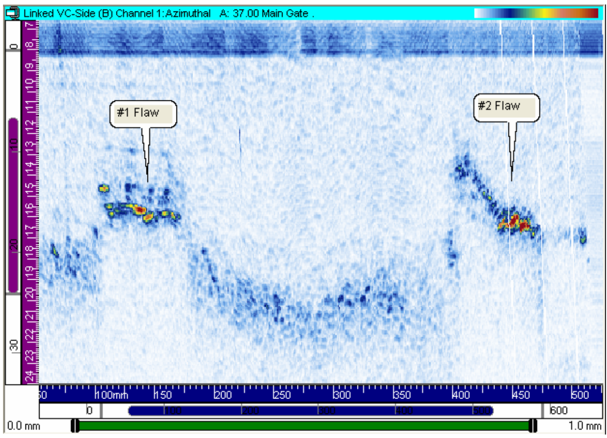

Figure 4. Side scan image at 37° ultrasonic shear wave

Table 1. Length estimation error compared to true length

	Flaw #1	Flaw #2
6dB Drop	-7.7 mm	2.2 mm
12dB Drop	-3.7 mm	4.2 mm
Fully Drop	2.2 mm	6.3 mm

True length and depth data are confidential, so only the discrepancy between the true data and measured data could be opened. Length sizing error compared to true length should be within 0.75″(19.05 mm) by ASME B & PV code, Sec. XI Appendix VIII supplement 2 and 3. So length estimation by 6dB, 12dB or fully drop method are all within the value and shows good results.

Sector scan images for flaw #1 and #2 are shown in Figure 5 and 6. Between the tip and root signal, there are many signal from flaw faces and it is easy to distinguish from flaw and geometric signal and estimate the depth. Other signals are from the geometry. For these flaws AATT (Absolute Arrival Time Technique) method can be used for depth estimation but RATT (Relative Arrival Time Technique) method can't be used for depth estimation because root and tip signal are not detected at the same degree. RATT method can only be used for really shallow flaw.

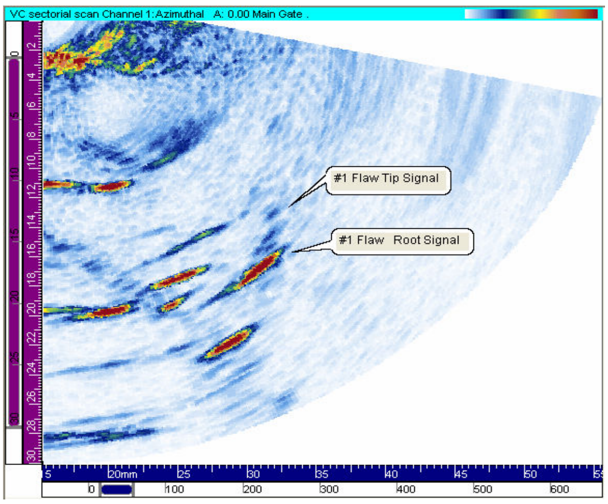

Figure 5. Sector scan image for #1 flaw depth estimation

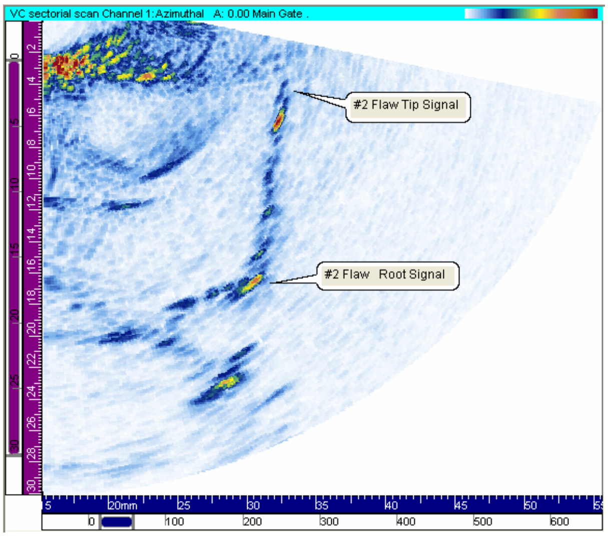

Figure 6. Sector scan image for #2 flaw depth estimation

Table 2. Depth estimation error compared to true depth

	Flaw #1	Flaw #2
A method	0.5 mm	1.4 mm
B method	-1.7 mm	-1.3 mm
C method	0.1 mm	-0.6 mm

Table 2 shows depth estimation result using 3 different methods. A method uses the value from measured specimen thickness minus measured remaining ligament. B method uses the value from true specimen thickness minus measured remaining ligament. C method uses corrected remaining ligament considering the ratio of measured and true specimen thickness. The deviation is -1.7 mm ~ 1.4mm and this value is within 0.125″(3.175 mm) by ASME B & PV code, Sec. XI Appendix VIII supplement 2 and 3 sizing acceptance criteria and have good accuracy. The accuracy could be increased by decreased degree interval between the waves and vice versa.

3. Conclusion

Phased array UT technique can increase the detection, availability and reliability compared to automated conventional pulse echo UT technique in piping examination. The results obtained from experiment can be used for procedure development to be qualified by the performance demonstration.

REFERENCES

[1] "ASME B & PV code, Sec. XI ", ASME, 95 edition with 96 addenda

[2] "Introduction to Phased Array Ultrasonic Technology Applications", RD-tech, 2004