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Development of Inspection Technique for Socket Weld of Small Bore Piping in Nuclear Power Plant

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1. Introduction

Failure of small bore piping welds is a recurring problem at nuclear power plants worldwide. In fact, socket welds account for more than 80% of weld failure in nuclear plants. Due to the lack of reliable inspection methods, in addition to the large number of welds, socket welds are not under volumetric inspection on a regular basis. However, socket weld cracking, has caused unplanned plant shutdowns in several nuclear plants. The losses incurred by unplanned shutdowns are significant; consequently, early crack initiation and crack detection, including the detection of fillet weld manufacturing defects, is of the utmost importance [1,2].

Current inspection techniques are not capable of reliably inspecting socket welds; therefore, new approaches are needed. The new technique must be sensitive to socket weld cracking, which usually initiates from the root, in order to detect the cracking during the early failure phase.

In 2008, Kori unit 3 experienced leakage from the drain line socket weld of a steam generator. From this experience, KHNP enforced a management program to focus on enhancing the reliability of small bore socket weld piping inspections. Currently, conventional manual ultrasonic inspection techniques are used to detect service induced fatigue cracks. But there was uncertainty on manual ultrasonic inspection because of limited access to the welds and difficulties with contact between the ultrasonic probe and the OD surface of small bore piping.

In this study, phased array ultrasonic inspection techniques are applied to increase inspection speed and reliability. Additionally a manually encoded scanner has been developed to enhance contact conditions and maintain constant signal quality.

2. Methods and Results

2.1 Phase Array Ultrasonic Technique

Phased array ultrasonic technique use probes that are composed of several piezoelectric crystals that can transmit/receive independently at different times. To focus the ultrasonic beam, time delays are applied to the elements to create constructive interference of the wave fronts, allowing the energy to be focused at any depth in the test specimen undergoing inspection. The phased array ultrasonic can control beam shape and direction electronically. Therefore, a single phased array ultrasonic probe can produce many different beams in rapid succession.

2.2 Socket Weld Piping

A socket weld is a pipe attachment detail in which a pipe is inserted into a recessed area of a valve, fitting or flange. In contrast to butt weld fittings, socket weld fittings are mainly used for small pipe diameter; generally for piping whose nominal diameter is NPS 2" or smaller.

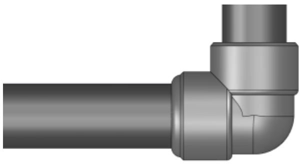

Fig.1 Generic configuration of socket weld

2.3 Phased Array Probe Modeling

The key element of the inspection system is the phased array probe. There are many parameters which can affect probe performance. Such as frequency, number of elements, and pitch etc.

To determine the characteristics of phased array probe, phased array modeling is considered.

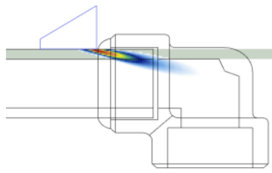

Fig. 2 Phased array UT probe modeling results for 80° incident angle

From the modeling results, probe specification is determined for manufacturing.

Table 1. Probe specification

Frequency	Type	Elements	Pitch	Width
3.5 MHz	Linear	16	0.4 mm	6.35 mm

2.4 Ring Scanner

Small bore socket welds, in nuclear power plants, have limited access and are in close proximity to other components. Therefore UT inspectors are encountering difficulties with contact and maintaining good coupling. In this study, a manually driven encoded scanner has been developed to overcome those limitations. Fig. 3 shows manual driven encoded ring type scanner for 1”(25.4 mm) OD.

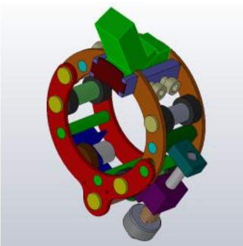

Fig. 3 Manual driven encoded ring type scanner

2.5 Experiment

Phased array ultrasonic inspection system was configured to evaluate detectability of the developed probe and scanner. Omniscan phased array pulser-receiver was used in this experiment. Fig. 4 shows inspection system layout.

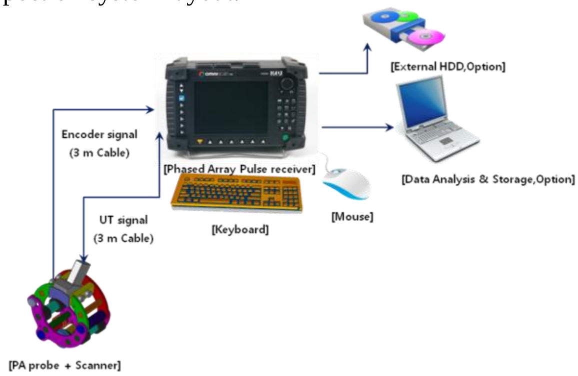

Fig. 4 Experimental setup of PA system

Two flawed 1”(25.4 mm) piping specimens which are made of stainless 304 austenitic material were used in this study. Fig. 5 shows one of the specimens that contains flaws.

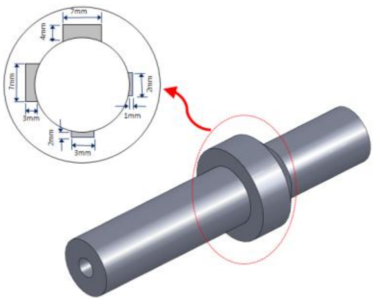

Fig. 5 Flawed specimen with EDM notch

The ring scanner, which is mounted with a 16 element phased array UT probe, is clamped onto the flawed specimen and rotated 360° around pipe. So the rotational angular position of the encoder signal is synchronized with the UT signal. In this study, the refracted angle of phased array probe is from 35° to 80°.

The acquired signal is analyzed by B-scan and C-Scan images for every angle. Fig. 6 shows B-scan display of EDM flawed specimen.

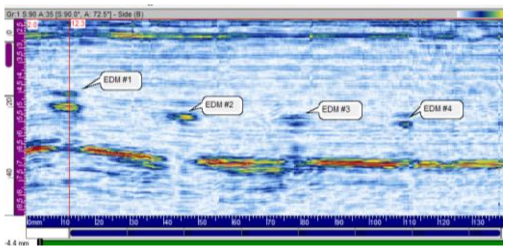

Fig. 6 B-Scan display of acquired signal from the flawed specimen.

From the experiment results, all implanted flaws in specimen are identified and length sized but depth sizing has too many uncertainties.

Table 2. Experimental results (unit mm)

No	Flaw Type	Detection	Conventional UT	Actual Length	Measured Length
1	LOF	○	○	3.81	3.4
2	Crack	○	×	3.81	3
3	Crack	○	○	12.19	10.2
4	LOF	○	×	7.3	5
5	LOF	○	○	7	7.4
6	LOF	○	○	7	7
7	LOF	○	○	3	3.5
8	LOF	○	○	3	3

3. Conclusions

A phased array UT technique and system was developed to inspect small bore socket welds. The experimental results show all artificial flaws in the specimen were detected and measured. These experimental results show, that the newly developed inspection system, has improved the reliability and speed of small bore socket weld inspection. Based on these results, future works shall focus on additional experiments, with more realistic flaw responses. By applying this technique to the field, we expect that it can improve the integrity of small bore piping in nuclear power plants.

REFERENCES

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