Sizing Techniques for Axial PWSCC Eddy Current Data in Steam Generator Tubing

Chan-Hee Cho, Min-Woo Nam, Dong-Hyun Jee, Jee-Hong Jung, Hee-Jong Lee
KEPRI, Nuclear Power Lab., 103-16 Munji-Dong, Yuseong-Gu, Daejeon 305-380, chancho@kepri.re.kr

1. Introduction

In the nuclear power plant, steam generator tubes have an important safety role because they constitute one of the primary barriers between the radioactive and non-radioactive sides. For this reason, the integrity of the steam generator tubing is essential in minimizing the leakage of water between the two sides of the nuclear power plant. The eddy current test is used to detect or size flaws which lie in steam generator tubing. The depth of volumetric indications can be evaluated approximately using the bobbin probe. However it is not easy to measure the size (depth and length) of axial or circumferential crack from eddy current data. Korea Electric Power Research Institute (KEPRI) has been developing the sizing technique for axial Primary Water Stress Corrosion Cracking (PWSCC). Many variables such as frequencies and calibration curves were analyzed to develop more accurate techniques. The round robin tests were carried out for axial PWSCC data using the thirteen different methods. The results of round robin tests will be compared with destructive examination results. It is expected that the size of axial PWSCC from eddy current data can be evaluated more precisely using the new technique to be developed.

2. Sizing Methodology for Axial PWSCC

EPRI (Electric Power Research Institute) ETSS (Examination Technique Specification Sheet) #96703.1 is used currently to evaluate the depth and length of axial PWSCC indications [1]. According to the ETSS, voltage normalization is performed in the circumferential lissajous window and is set on the 100% axial notch at 20 volts. It is necessary to adjust the span such that the 40% OD (Outside Diameter) axial notch is 1 division at 300 kHz and to set phase so that the 40% ID (Inside Diameter) axial notch is 15 degrees at 300 kHz. A phase curve is established on the 300 kHz raw channel using 100, 60 and 40% ID axial notches.

Prior to applying this technique to the field evaluation, the round robin tests were carried out by the domestic analysts. Eddy current data used in these tests were collected from the field inspections of nuclear power plants in Korea. The results for the depth sizing are shown in Fig. 1 and for the length in Fig. 2. X-axis in Fig. 1 represents the analyzed maximum depth values of the indications by ISI (In-service Inspection) vendor analysts. Y-axis represents the analyzed maximum depth values of the indications by KHNP (Korea Hydro & Nuclear Power Co.) analysts as the reference values. The total number of data is 225. The standard deviation is 5.64% and the correlation coefficient is 0.93 for the maximum depth in Fig. 1. The standard deviation is 0.36 mm and the correlation coefficient is 0.71 for the length in Fig. 2. The standard deviation for the depth of axial PWSCC is larger than 1.45% of axial ODSCC in the previous work [2]. Therefore it is necessary to develop the new sizing techniques for axial PWSCC.

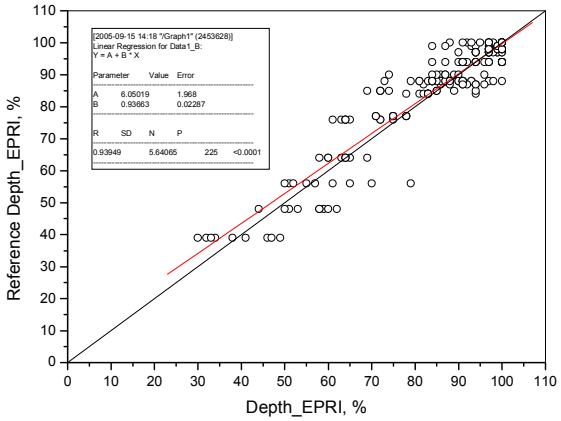

Fig. 1 Round Robin Test Results for Maximum Depth

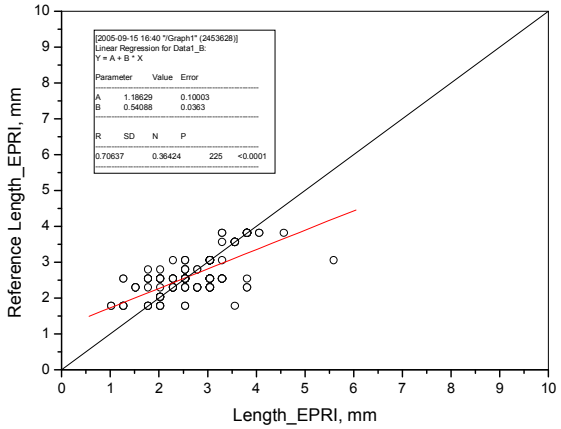

Fig. 2 Round Robin Test Results for Length

3. Round Robin Test

There are four types of crack indication in steam generator tubing such as axial primary water stress corrosion cracking (PWSCC), axial outside diameter stress corrosion cracking (ODSCC), circumferential primary water stress corrosion cracking and circumferential outside diameter stress corrosion cracking. Crack sizing for axial ODSCC indications is

performed currently in accordance with Westinghouse 00-TR-FWS-023 Rev.1 [3]. EPRI ETSS #96701.1 was developed to use in sizing the depth and length of circumferential PWSCC in the expansion transition [4]. However it is widely used in other locations of steam generator tubes. The sizing methodology for the circumferential ODSCC is based on the report EPRI TR-107197-P1 [5].

Due to the large deviation of sizing results for axial PWSCC, KEPRI has been developing the new sizing technique using Kori unit 1 retired steam generators (RSG). The Kori unit 1 RSG has various types of indication. The eddy current tests were performed to identify the tubes with crack and the collected data were analyzed by KEPRI and KHNP analysts. Flawed tubes were pulled by KPS (Korea Plant Service & Engineering). The eddy current tests were carried out for these segments after pulling. They are being examined destructively by KAERI (Korea Atomic Energy Research Institute).

Many variables such as frequency, calibration type, calibration points, and lissajous windows were analyzed to develop more accurate techniques. Thirteen different methods were derived from the parameter analysis. Table 1 shows these different methods.

Table 1. Various Methods for Round Robin Tests

Channel	Fq.[1)]	Calibration Type	Calibration Points	LW[3)]
P1	400	Amplitude	100, 60, 20	ML[4)]
P2	300	Amplitude	100, 60, 20	ML
P3	300	Amplitude	100, 60, 40	ML
P4	400	Phase	100, 60, 20	ML
P5	300	Phase	100, 60, 20	ML
P6	300	Phase	100, 60, 40	ML
P7	300	A on MP[2)]	1 pt wear scar	C-Scan
P8	400	Amplitude	100, 60, 20	C-Scan
P9	300	Amplitude	100, 60, 20	C-Scan
P10	300	Amplitude	100, 60, 40	C-Scan
P11	400	Phase	100, 60, 20	C-Scan
P12	300	Phase	100, 60, 20	C-Scan
P13	300	Phase	100, 60, 40	C-Scan

[1)] Frequency
[2)] Amplitude Based on Maximum Depth Phase
[3)] Lissajous Window
[4)] Main Lissajous

The round robin tests for these methods were carried out by domestic analysts using Kori unit 1 RSG eddy current data. All analysts are fully qualified for the data analysis. The ten different results were obtained for the above thirteen methods from the round robin test. The results will be compared with destructive examination results and the best methods will be selected for the evaluation of axial PWSCC data. The new technique to be developed would be applied to the field evaluation through the Steam Generator Management Program [6].

3. Conclusion

There are four types of crack indication in steam generator tubes such as axial PWSCC, axial ODSCC, circumferential PWSCC, and circumferential ODSCC. EPRI ETSS #96703.1 is currently used to evaluate the depth and length for axial PWSCC indications. The results of the round robin tests in accordance with EPRI ETSS #96703.1 show that the standard deviations of the maximum depth and length are 5.64% and 0.36 mm, respectively. The correlation coefficients for the maximum depth are 0.93 and 0.71 for the length. The standard deviation of the maximum depth for axial PWSCC is relatively larger than axial ODSCC of 1.45% in the previous work. Therefore KEPRI has been developing the new sizing technique for the axial PWSCC indications using the Kori unit 1 RSG data. Sizing technology is dependent on the frequency, calibration type, calibration points and lissajous windows. The thirteen different methods were derived from the parameter study. The results for these methods will be compared with the destructive examination results. It is expected that the best sizing technique for axial PWSCC data would be developed.

REFERENCES

[1] Electric Power Research Institute, Performance Demonstration Database: Appendix A, Examination Technique Specification Sheet ETSS #96703.1 Rev. 10, 2001.

[2] Chan-Hee Cho et al., Round Robin Test for Crack-Sizing Methodology in Steam Generator Tubes," Transactions of the Korean Nuclear Society Spring Meeting, 2006.

[3] Westinghouse Electric Company, Plus-Point Coil Sizing Study for Axial Crack Profiling, Report No. 00-TR-FWS-023 Rev. 01, 2001.

[4] Electric Power Research Institute, Performance Demonstration Database: Appendix A, Examination Technique Specification Sheet ETSS #96701.1 Rev. 7, 2001.

[5] Electric Power Research Institute, depth-Based Structural Analysis Methods for Steam Generator Circumferential Indications, EPRI TR-107197-P1, 1997.

[6] Korea Hydro & Nuclear Power Co., Integrated Guidelines of Steam Generator Management Program, 2005.