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Analysis on Axial Cracks of Steam Generator Tubes Using Multi-Parameter Algorithm

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1. Introduction

An eddy current testing (ECT) has been employed as an automatic testing method to measure defect morphology on steam generator (SG) tubes in nuclear power plants. A feature of an evaluation capability not only to measure of crack location but also to estimate a crack shape is highly desirable. In this paper, laboratory grown SCC and natural SCC defects of pulled steam generator tubes were nondestructively analyzed by using the MPA (Multi Parameter Algorithm) which is operated in the MATLAB environment. The experimental results of two examination methods, destructive and nondestructive tests, are described and evaluated comparatively.

2. Experimental

2.1 Specimens preparation

We have prepared laboratory grown SCC and pulled steam generator tubes. Laboratory SCC was an Alloy 600 tube of which the outer diameter was 7/8-inch and it was sensitized at 600°C for 48 hours in an inert gas atmosphere to make the cracks easily. A detail description of the Alloy 600MA tubes is in Table 1. Then the outside of the tube was exposed to a 1M sodium tetrathionate solution at room temperature by pressurizing the inside of the tube. Main form of the degradation of the pulled SG tubings was a pitting, primary water stress corrosion cracking (PWSCC), outer diameter stress corrosion cracking (ODSCC) and inter granular attack (IGA). The selected tubes that were based on the ECT signal during an in-service inspection (ISI) were transferred to a hot laboratory at the Korea Atomic Energy Research Institute (KAERI).

2.2 Eddy Current Testing of SG tubes

The ECT data was collected by using the MIZ-30 acquisition system with a magnetically biased rotating pancake coil (RPC) probe. Before acquiring the ECT data for the tubes, a copper piece was attached on to the tube surface to identify the position of the flaws. The defect signals may be corrupted by noise and non-defect or unwanted signals deriving from the variation of the lift-off of the probe and the structures out side the tubes. These corrupted signals cause negative impacts of a inaccurate detection and characterization of defects. The magnetically biased MRPC (Motorized Rotating Pancake Coil) probe was used to compensate for a distortion of the ECT signals. Though the sensitivity of this probe is less than a normal probe, it has a benefit for tubes where the ECT data was corrupted by a noise of the magnetic properties.

2.3 Destructive analysis of SG tubes

Prior to the destructive examination, the SG tubes were non-destructively examined to estimate the information on the defects such as the locations, directions and OD or ID, and then the crack morphology of the samples were observed macroscopically with an optical and scanning electron microscopy (SEM). The graphical comparisons of the depths were obtained with a fractography and NDE results.

3. Results and discussion

3.1 Data analysis by MPA

The data from the eddy current inspection both laboratory grown SCC and pulled tubes was used to evaluate the performance of the multi parameter algorithm. Figure 1 shows a terrain plot of the relative OD depth profile for the crack zone and it is a part among several processing stages in an MPA when analyzing defects. From Figure 1-(a), we can confirm the only one defect was detected and there are two indicators of Cu and TTS which can be specified to identify the location of defects randomly by a user. To obtain a depth profile, a cross-bar is positioned on the images of a defect that have a maximum depth. The sample of the laboratory produced SCC had a maximum depth of over 80% of the tube wall (TW) penetration in depth and a 13 mm long axial crack in length.

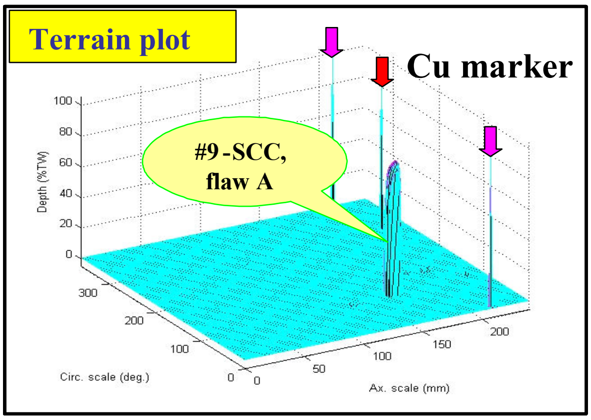

Figure 1-(a) Terrain plot of relative OD depth profile

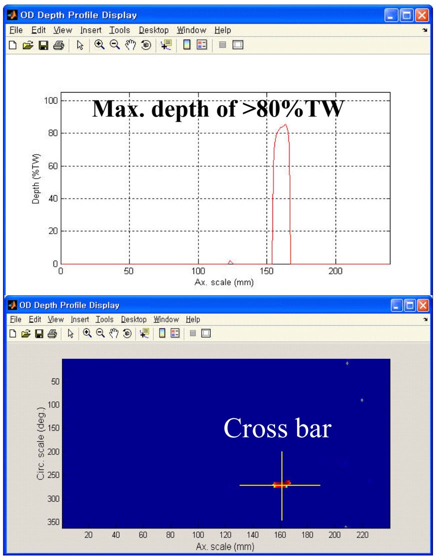

Figure 1-(b) Flaw depth profile on a point with maximum depth (Top) and a display of the defect. (bottom)

In order to confirm the MPA reliability, depth profiles (fractography) from the destructive examination were compared with results analyzed from the multi parameter algorithm. The graphical comparisons are presented in Figure 2. Because the cracks are so tight and a crack opening is not enough to show a big ECT signal, it was hard to quantify the depth accurately. Due to this reason, the difference between the estimation results could be understandable.

4. Conclusions

- The data from a eddy current inspection of both a artificial SCC produced in a laboratory and pulled tubes were used to evaluate the reliability of a multi parameter algorithm.
- Magnetically biased probe was used to compensate for the corrupted signals by noise or artificial signals but the sensitivity of the probe was less than a non-magnetically probe.
- The difference in the depth estimation could be explained as follows: the crack is so tight and crack opening area (COA) is not enough to recognize defect signals fully.

REFERENCES

[1] S.Bakhtiari, J.Y.Park, D.S.Kupperman, S.Majumdar, W.J.Shack, Advanced Nondestructive Evaluation for Steam Generator Tubing, NUREG/CR-6746.

[2] D.S.Kupperman, S.Bakhtiari, W.J.Shack, J.Y.Park, S.Majumdar, Evaluation of Eddy Current Reliability from Steam Generator Mock-Up Round-Robin, NUREG/CR-6785.

[3] S.Bakhtiari, J.Y.Park, D.S.Kupperman, and W.J.Shack, Computer-aided analysis of eddy current rotating probe data.

[4] Ch.Nam-Gung, Y.S.Lee, S.S.Hwang, H.P.Kim, Depth Analysis of Mechanically Machined Flaws on Steam Gernerator Tubings Using a Multi-Parameter Algorithm. Korean Nuclear Society Autumn Meeting, October 28-29, 2004.

Table 1 Chemical compositions of alloy 600MA tube (wt %)

Alloy	C	Si	Mn	P	Cr	Ni	Fe	Co	Ti	Cu	Al	B	S	N
600MA	0.025	0.05	0.22	0.07	15.67	75.21	8.24	0.005	0.39	0.011	0.15	0.001	0.001	0.01

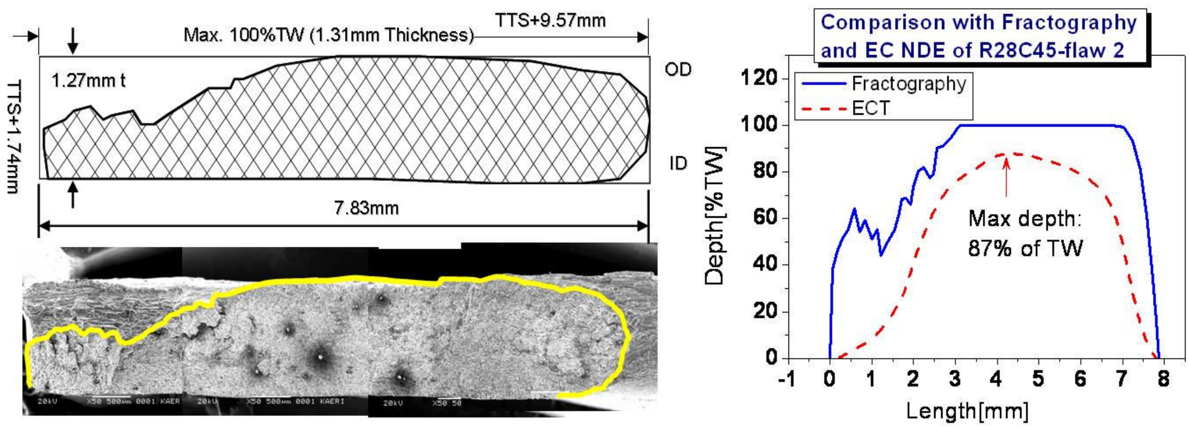

Figure 2 Crack morphology of pulled steam generator tubes (left) and comparison depth profile of DE and NDE results for specimen with axial cracks (right).